Cost Efficiency in the UK Life Insurance Industry in the post-Global Financial Crisis Period

by
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Abstract

The aim of this research project is to adopt a two-stage approach for empirically measuring and determining the level of cost efficiency in the UK Life Insurance industry during and after the Global Financial Crisis (GFC). Stage one employs a Data Envelopment Analysis (DEA) technique with Variable Returns to Scale (VRS) to estimate the cost efficiency scores for the whole UK Life Insurance Industry for the period 2007 to 2015. In the second stage, a panel Tobit regression technique is used to examine the effects on cost efficiency of a set of determinants that are largely drawn from the recent literature on Financial and Risk Management (FRM). The findings suggest that the average cost efficiency in this period was lower than the level previously reported in the literature, but, by 2015, a clear improvement is noted. The findings also suggest that some potentially effective measures to improve operational efficiency include the reduction of the use of reinsurance, increasing firm size and relocation of office space away from Central London.

Keywords: Cost Efficiency, Life Insurance, Data Envelopment Analysis, Global Financial Crisis, Financial and Risk Management
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Chapter 1: Introduction
1 Introduction

This research project, entitled Cost Efficiency in the UK Life Insurance Industry in the post-Global Financial Crisis Period uses empirical data for the UK Life insurance industry in the period 2007 – 2015 to analyse cost efficiency for the UK insurance industry and its determinants. This section provides a brief overview of the industry, the aims and objectives of this project and how it will contribute to practice and the literature. This section also includes a reflective section by the researcher, which highlights their professional context, philosophical paradigm and motivation for conducting the research. Section 2 summarises the critical conceptual and empirical literature review that was conducted as part of this project, while Section 3 provides details of the methodology that was employed in the study. Section 4 discusses the results of the project, and the report concludes with conclusions in Section 5.

1.1 Overview of the UK Insurance Industry

1.1.1 High-level context of the Industry

The UK Insurance Market is the 4th largest in the world by Premiums Written, after the United States of America (U.S.), China and Japan\(^1\). It is therefore the largest in Europe, and also has one of the highest penetration rates in the region (see Figures 1-1 and 1-2 below). This suggests that the performance of this industry is important both in the UK, and within the Global context.

The UK Insurance market is dominated by the Life insurance sector, which has made up around 75% - 85% of the whole industry by Gross Written Premiums (GWP) over the decade up to 2015 (see Figure 1-3). This sector is therefore the focus of this research project.

\(^1\)Source: https://www.swissre.com/dam/jcr:a160725c-d746-4140-961b-ea0d206e9574/sigma3_2018_en.pdf
As at YE15\(^2\), the UK Life insurance industry was made up of 95 legal entities (down from 147 in 2007), some of which are part of wider Financial Services groups (e.g. Abbey Life was owned by Deutsche Bank), while some were owned by a single parent (e.g. Aviva Life and Pensions and Friends Life Limited were both owned by Aviva plc). As well as providing traditional Life insurance services (e.g. term assurance claims, annuity payments), the industry is a significant player in the Asset Management arena, with around £1.6 trillion of assets under management. The average profit margin across the industry was 12.5% in 2015 (made up of £224.6 trillion of revenue – which mainly comes from premiums written, and £196.2 trillion of expenditure – which is driven by claims payments).

Firms in the industry are typically owned by public or private shareholders, but could also be wholly owned policyholders (i.e. mutual organisations). Aviva plc is an example of a shareholder-owned firm, while Liverpool Victoria and Royal London are examples of mutual firms\(^3\).

There have been a number of recent developments in this industry, which suggest that a fresh look at efficiency measurement and drivers is necessary. Some of these developments are discussed in sections 1.1.2 to 1.1.9 below.

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\(^2\) Sourced from SynThesys Life 10.1 Database, and excludes firms without all of expenses, claims and asset data

\(^3\) Source: [www.aviva.com](http://www.aviva.com), [www.lv.com](http://www.lv.com) and [www.royallondon.com](http://www.royallondon.com)
Figure 1-1: European insurance market size, by Gross Written Premium (£M), FY’15


Figure 1-2: Insurance penetration, expressed as Gross Written Premium/GDP (%), FY’15

1.1.2 The Global Financial Crisis
The significant role of the UK Life Insurance industry within the European and Global context has seen it go through significant events and changes in recent years. As part of the Financial Services industry, it was within the epicentre of the Global Financial Crisis, which saw the closure or bailout of some multinational banking and insurance institutions (e.g. Lehman Brothers⁴ & American International Group⁵). To its credit, the UK insurance industry did not experience any explicit closures or bailouts, perhaps attributable to a risk-based capital regulatory regime that had been introduced by the Financial Services Authority (FSA) in 2004, called ‘Individual Capital and Adequacy Standards (ICAS)’⁶. However, the crisis might have left some individual companies with weaker balance sheets, which arguably squeezed financially non-critical (but commercially critical) budgets like Research & Development. This in turn, might have left companies restricted in their ability to invest in the most technically efficient methods to run their businesses (e.g. a move from traditional

---

⁴ Source: https://www.investopedia.com/articles/economics/09/lehman-brothers-collapse.asp
⁵ Source: https://www.forbes.com/pictures/eddk45fhjy/aig-bailout-in-brief-5/#6ae298ec6857
in-house computer servers to cloud\textsuperscript{7} computing). It also arguably made more companies vulnerable to takeover bids, as weaker companies sought the protection of stronger balance sheets for continued survival, while the stronger companies might have looked for value creation by realising synergies with other companies. In addition, the regulatory response of the UK government to the crisis was to abolish the FSA and replace it with two regulators\textsuperscript{8}: the Prudential Regulatory Authority (PRA), which focusses on the financial soundness of all financial institutions; and the Financial Conduct Authority (FCA), which aims to regulate the products that insurance and other financial institutions sell to customers. Although PRA & FCA appear to be mutually exclusive, they are arguably going to overlap from time to time. In addition, increased focus in one area potentially leads to increased regulation in that area. This could therefore all amount to a potential increase in compliance costs for insurance companies, thus reducing efficiency from a cost perspective.

1.1.3 The Sovereign Debt Crisis
Whilst the full extent of the Global Financial Crisis was still unfolding, the European Sovereign Debt crisis also began to unfold from 2010 to 2012, creating challenges for – amongst other economic players - the Insurance Industry in Europe (Gonzalez et al. (2017)). Although there does not appear to be any relevant literature in relation to the impact of this crisis-within-a-crisis on the UK Insurance Industry, it is unlikely to have been spared, because EU regulations on Insurance Solvency (discussed in more detail in Section 1.1.4) apply favourable regulatory capital treatment if an insurance company in one country wants to invest in the sovereign debt of another EU country. Some UK insurance companies might therefore have had exposure to Sovereign bonds of affected countries like Spain and

\footnote{Basic information on cloud computing can be found here: https://azure.microsoft.com/en-gb/overview/what-is-cloud-computing/}

\footnote{Source: https://www.barnett-waddingham.co.uk/comment-insight/blog/2013/04/03/goodbye-fsa-hello-pra-and-fca/}
Greece. This could therefore have led to companies either retaining earnings to support the capital position after allowing for any defaults, or raising more capital externally. Any externally raised capital would have increased costs for the affected insurer, and therefore potentially impacted on cost efficiency. In addition, if the cashflows of these bonds were being used to match policyholder benefit payments, affected companies might have needed to rebalance their asset portfolios to restore the match. This could have also affected efficiency, by increasing the cost of doing business (through portfolio rebalancing costs) without reducing the output (i.e. benefit payments).

1.1.4 Solvency II and IFRS 17
Running alongside any UK-specific regulatory changes, were preparations for a holistic approach to the regulation of financial soundness of insurance companies across Europe called ‘Solvency II’, which came into effect on 1 January 2016. Solvency II replaced ICAS in the UK, and the industry view is that this has resulted in more onerous capital requirements and maintenance costs than under the ICAS regime\(^9\). If a company needed to raise this additional required capital, it would have incurred a cost of this new capital. In addition, the new regulatory regime appears to have created additional headcount for some companies (e.g. it makes specific reference to a Risk function, leading to a need for Risk professionals that might not have been previously required by insurance companies). This appears to have further reduced efficiency from a cost perspective.

Work has also begun on implementing a major change to the financial reporting landscape of the insurance industry from a global perspective. This initiative – known as IFRS17 - is being led by the International Accounting Standards Board, and is expected to become

\(^9\) Source: ‘Solvency II and Current Economic Environment – Impact on Consumers’ by the Institute & Faculty of Actuaries.
effective for annual reporting periods beginning on or after 1 January 2021\textsuperscript{10}. Although it is currently unclear if this major change will result in a long-term ongoing increase to a company’s cost base, industry practitioners expect it to increase the running costs in the industry\textsuperscript{11}, which would put a further strain on ongoing efficiency from a cost perspective. In addition, a project of this magnitude is likely to result in significant costs in the implementation phase.

1.1.5 Pension Freedoms and Equity Release Mortgages

The post-2008 period has seen another fundamental regulatory change, which allowed maturing pension savings to be available as cash, as opposed to automatically purchase an income for life (also known as an annuity)\textsuperscript{12}. This has risked reducing efficiencies that come from economies of scale for Life Insurance companies, since companies would now need to cover any fixed expenses they could not pass on to the reduced number of policyholders. It also potentially increased insurance companies Research and Development costs, as they sought to find alternative future income streams that were lost due to this regulatory change.

One innovation that some insurance companies have turned to in response to falling income streams is the Equity Release Mortgage. This product recognises that many UK pensioners have valuable capital locked in their residential properties, so allows policyholders to release this value during their retired life, in exchange for part or all of the residential property on death\textsuperscript{13}. However, this is a regulatory capital-intensive product (due to the

\textsuperscript{10} Source: https://www.ifrs.org/issued-standards/list-of-standards/ifrs-17-insurance-contracts/
\textsuperscript{11} Source: http://www.theactuary.com/news/2018/05/ifrs-17-to-be-more-costly-than-solvency-ii/
\textsuperscript{12} Source: https://www.pensionsadvisoryservice.org.uk/about-pensions/pension-reform/freedom-and-choice
\textsuperscript{13} Details of Equity Release Mortgages: https://www.moneyadvisescervice.org.uk/en/articles/equity-release
associated complex risks that are not publicly assessable), which might inadvertently decrease the efficiency of insurers that offer it.

### 1.1.6 Insure-tech companies

Entrance into the industry of insure-tech companies like Vitality\(^\text{14}\) has also put pressure on business volumes of traditional insurance companies, thus threatening their Economies of Scale. These new companies have little or no legacy systems, and are arguably able to offer the same benefit as a traditional insurer with less inputs (e.g. capital), because – for example – much better knowledge of the policyholder through smart watch data means less prudent reserves for the policy need to be set up.

### 1.1.7 Prevailing Market Conditions

The impact of the regulatory changes discussed above has been compounded by the low interest rate environment in the aftermath of the Global Financial Crisis (see Figure 1-4). The Solvency II Balance Sheet is made up of the following key items at a high level:

\[
\text{Distributable Surplus} = \text{Market Value Assets} - \text{Present Value of Policyholder Liabilities} - \text{Risk Margin} - \text{SCR}
\]

Where:

- SCR, or Solvency Capital Requirement is the regulatory capital under the Solvency II rules; and
- Risk Margin is a regulatory requirement for an insurance company to hold an amount to pass on to a third party in the event of insolvency. This amount would allow the third party to pay for the cost of capital raised to cover inherited

\(^{14}\) https://www.vitalitygroup.com/
regulatory capital requirements in all future years until the last policyholder goes off the books. The cost of capital in each future year is then discounted to the present day using the current and relevant forecast interest rates, with this present day value being high when interest rates are low (and vice versa).

The prevailing low interest rate environment has therefore led to high Risk Margins. This is especially so in the Life Insurance sector, where products like annuities and death in service spouse’s pensions mean it could be a few decades before the last policyholder goes off the books, meaning many more years for an annual cost of capital to apply. The very long-term nature of the Risk Margin commitment in this case also makes it difficult to manage interest rate volatility, since it tends to be difficult find assets in the open market that can mirror such a long-term commitment. Companies therefore usually resort to holding an additional capital buffer above the regulatory SCR to absorb this interest rate volatility, thus increasing the input required for a given level of output.

Existing business on 1 January 2016 (when Solvency II became effective) was effectively shielded from the additional capital requirements via transitional arrangement (the Regulator acknowledged that the business was written in a different regulatory regime). However, new business from the implementation date needs to fully meet these additional capital requirements. This suggests that companies have either had to adjust prices upwards or reduce the profit margin in the price (or both) to account for these additional capital requirements. The former is made more challenging by the pension freedoms discussed in section 1.1.5, since it makes the purchase of an annuity even more unattractive compared to the alternatives.
Interest rate levels are also important for insurers, because they can influence a firm’s cost of capital, so could therefore influence efficiency or inefficiency. For example, a loan to a firm can be based on the bank base rate plus a margin\textsuperscript{15}.

Figure 1-4: UK Interest Rate History

![UK interest rates graph]

Source: Bank of England

Another prevailing feature of current market conditions – which affects the Market Value of Assets part of the Distributable Surplus calculation – is the high risk/return efficiency in a subdued investment market (see an example in Figure 1-5 below, which shows a lot of asset classes clustered around the efficient frontier, and shows a downward shift of this frontier year-to-year). Investment managers have arguably increased this efficiency post-2008 to ensure they optimise the returns they can get for a given level of risk. This has therefore left insurance companies with limited scope to increase efficiencies on the investment side, and pointed further to the need to reassess efficiencies elsewhere on the balance sheet.

\textsuperscript{15} An example of this can be found here: http://www.ddjcap.com/documents/ddjopportunistichighyieldfund-comm-20151112.pdf
1.1.8 Current industry activity and potential inefficiency levels

All these activities post-2008 have led to significant activity in the UK insurance industry, with ‘efficiency’ and/or ‘cost-savings’ being cited as reasons behind key business decisions. Some examples can be found in a survey of industry practitioners by Finances Services consulting firm PwC entitled European Life Insurance Back Book Management 2017\(^\text{16}\). Firstly, the survey found that “minimising expenses remains high on the agenda for many firms, and is a significant driver of consolidation activity and management of cost-cutting and efficiency programs”. The survey also concluded that the UK insurance market was expected to remain at the forefront of consolidation activity in Europe. Secondly, it also specifically highlighted the changing regulatory environment as one of the drivers for the

increased cost burden. Finally, companies were also found to be looking at the disposal of non-core businesses and changes to their investment strategies to improve efficiencies. These recent industry developments and the increasing importance of capital management in the industry suggest a need to understand the current capacity to improve cost efficiency. This will help industry practitioners make informed strategic decisions and potentially help to reduce the impact of the new financial and regulatory landscape eating into value and profits. Understanding the commercial effects of the regulatory changes can also provide a useful input into policy-making decisions.

There is wide variety of potential categories of efficiency or inefficiency drivers in the industry, which practitioners could consider as part of attempts to improve efficiency at their firms. One such category is Financial Risk Management, and this is introduced in section 1.1.9 below.

1.1.9 Financial Risk Management in the UK Insurance Industry

Financial Risk Management\(^{17}\) appears to be a key part of the UK Insurance industry, with around 15% reinsurance cover, 59% Free Asset cover and 23% of liquid assets across the industry, as well as 30% of firms making use of Derivative instruments as at YE15\(^{18}\). Bartlett et al. (2008) looked at overall Risk Management in this industry in more detail, by reviewing results of relevant surveys, and concluded that there is evidence to indicate that insurers’ risk management practices have been improving significantly over time, but there was still room for the industry to do much better than it is doing to manage its risks. One of the obstacles to effective risk management in the UK insurance industry that was cited by Bartlett et al. (2008) was the cost of implementing it. It is therefore worth exploring if


\(^{18}\) According to summary data compiled from the SynThesys Life 10.1 Database.
common Financial Risk Management tools are making firms less cost-efficient, or whether the opposite is true, with the use of these tools actually leading to improved efficiency (and thus providing evidence of support for Risk Management from a commercial perspective).

The various aspects of the UK Life Insurance industry discussed in this section influenced the formulation of this study’s purpose and research questions. These are discussed in section 1.2 below.

1.2 Purpose and Research Questions

The purpose of this study is to conduct an empirical investigation on the level of cost efficiency in the UK Life Insurance industry during and after the Global Financial Crisis, as well as test the statistical significance of a sample of potential drivers of efficiency that are largely drawn from the area of Financial and Risk Management. This purpose has helped to shape the two key research questions in this study. The first question asks about the level of cost efficiency in the industry at the end of each year, from 2007 to 2015, and what the average level was over the whole period. The second question looks to explore the statistical significance of reinsurance cover, financial derivative use, free assets on the Balance Sheet, the level of liquid assets, the size of a company and a Central London office location on insurance firms’ cost efficiency inefficiency. The next section is a reflective summary of the motivations behind these research objectives and research questions.

1.3 Researcher’s Motivations

The extract below is from my Curriculum Vitae, and summarises who I am within my professional context:

I am an actuary with 15 years’ actuarial experience (including 8 years post-qualification). I have worked in both consulting and industry environments, which has led to extensive Employee Benefits Consultancy and Life Industry exposure, as well as some Non-Life Industry exposure. I currently
manage an actuarial team of seven (including five qualified actuaries), and am one of five Heads in Canada Life’s Corporate Actuarial department. My team’s responsibilities include; Capital Management and Optimisation, Capital Methodology Review, Stress and Scenario Testing, Financial Planning and Regulatory Engagement Support.

Based on the paragraph above, I consider my context to have a few professional context layers, as shown in Figure 1-6 below.

*Figure 1-6: The Researcher’s Professional Context*

I view my current role at Canada Life as straddling all the layers above, because I see Capital projects in Insurance as contributing to an insurer’s strategic Business objectives within the Financial Services industry in general, and the Insurance industry in particular. However, due to the nature of products transacted by insurers (which are mainly focussed on statistically uncertain future events), these Capital projects rely significantly on the Actuarial skillset.
As an actuary by training, I am partial to following Popper’s Principle of Empirical Falsification, which states that a hypothesis can be tested by empirical experiment (Popper, 1959). My research questions therefore emerged by reading widely on empirical studies in efficiency research in the insurance industry, and then looking in more detail at the UK and European literature, to explore what had been explored, and where the gaps were. Having spotted what appeared to be a gap that was relevant to my Professional Context, I then sought to find out what data was available to perform my own empirical study for the UK market from the perspective of my Professional Context. I then formulated my research questions on the back of this.

Even though I am partial to empirical studies, there was still a need to guard against viewing efficiency as a purely scientific topic, with little debate about how it is measured or what drives it. There was also a need to appreciate the limitations of my findings. For example, the findings might only be generalizable within the UK industry, and for a specific amount of time within that industry. That said; I also needed to acknowledge that the approach to this study was going to be influenced by this actuarial training.

As well as a professional interest in the subject of insurance efficiency, this study was also motivated by a desire to add a practitioner perspective to this research area, which appears to be dominated by academic researchers. While this report has been written in a scholarly manner, there are a lot of examples throughout that reflect this practitioner perspective.

In addition to my individual interest, the findings of this study might also be of interest to professional and industry bodies within my professional context. For example, the Institute and Faculty of Actuaries (IFoA) and the Association of British Insurers (ABI) have recently
highlighted research done at the University of Kent on Equity Release Mortgages as something that might be useful for practitioners\textsuperscript{19}. A study on a topical issue such as efficiency might therefore potentially attract similar industry-wide interest. There might also be interest in the findings from my senior managers at Canada Life, since their firm will be included in the analysis, suggesting that the findings will be directly relevant. These motivations and biases, as well as my chosen philosophical underpinning, influenced the literature I have reviewed in this study. This is discussed in Chapter 2.

\textsuperscript{19} Source: https://www.actuaries.org.uk/documents/review-no-negative-equity-guarantee
Chapter 2: Literature Review
2 Literature Review

Review of literature in this project provides a conceptual framework to look at efficiency within the overarching context of market regulation, and its influence on competitive advantage. This framework provides regulatory conditions which need to be met before efficiency management can be used to drive company performance. There also appears to be a significant amount of empirical literature on efficiency in the insurance industry. These studies mainly differ by the country in which the study is conducted (e.g. Ward (2002) in the UK, and Xie (2010) in the USA), the types of Efficiency investigated (e.g. cost or profit), the efficiency methodologies applied (e.g. Data Envelopment Analysis or Stochastic Frontier Approach), Insurance Inputs and Outputs (i.e. differing approaches of measuring intangible financial services such as risk pooling) and the efficiency determinants investigated (e.g. corporate governance or product distribution systems). The conceptual framework as devised by the author on the basis of the existing strands within the literature can be seen on Figure 2-1 below. The literature review is then discussed in more detail in the rest of this section.
Figure 2-1: The Conceptual Framework for the Research Project

- Regulation of Market Competition
- Command Markets
- Theory of Structure, Conduct & Performance
- Market Structure
- Firm Conduct
- Nature of Efficiency
- Efficiency Methodologies
- Efficiency Frontier Form
- Efficiency Inputs and Outputs
- Efficient Structure Hypothesis
- Efficient Structure Hypothesis
- Efficiency Scores
- Drivers of Efficiency
- Competitive Advantage for an Organisation
- Resource Based View
2.1 Regulation

The source of a company’s ability to outperform another company can arguably be found in the prevailing regulation around market competition. In their simplest form, market competition regulations can be seen to either encourage (liberal and coordinated markets\textsuperscript{20}) or discourage (command markets\textsuperscript{21}) competition. The nature of the regulation would then determine the performance paradigm that applies. The diagram above suggests that efficiency research can only be conducted in markets that encourage competition. The following paragraphs explore if the UK Insurance industry is suitable for efficiency research from a regulatory perspective.

The UK Insurance Industry is part of the European Insurance Industry, through the UK’s membership of the European Union (EU). Through the Treaty of Rome of 1957, Insurance and other industries were set on a path of a single, unified market across the EU. Campbell et al. (2003) discuss the relevant legislative developments since the Treaty of Rome, which culminated in The EU’s Third Generation Directives for Life and Non-Life Insurance in 1994. This created a single passport enabling free access to establish insurance offices in any EU country. The UK Insurance Industry has therefore become more open due to these European Directives. Although the UK is in the process of leaving the European Union, these directives are expected to be transposed into UK law at the date of exit, and would therefore still apply in the short to medium term. In addition, foreign insurance companies have been able to enter the market for many years (e.g. Canada Life started its UK

\textsuperscript{20} The term is taken from Peter A. Hall and David Soskice (2001): ‘Varieties of Capitalism. The Institutional Foundations of Comparative Advantage’ Oxford University Press.

\textsuperscript{21} A ‘command economy’ is defined by Hilbert and Wright (2017) as one in which there is a high of level control of economic activity by the elected and appointed officials of a nation state.
operations in 1903\textsuperscript{22}). Local UK regulation is also geared towards encouraging competition, with both the PRA and FCA having the promotion of effective competition as a key objective\textsuperscript{23}.

Although the classification of a liberal/coordinated or command market is subjective, the UK Insurance Industry is considered to be a liberal market for the purpose of this research, on the basis of the regulatory analysis discussed above. This view is arguably supported by the research done by Hall and Soskice (2001), where they specifically compared liberal and coordinated economies, and concluded that the UK as a whole was a liberal economy that had competitive advantage in the high-tech and services sectors (of which UK Life Insurance industry is a part). They also add that the aims of economic policies in a liberal market like the UK include minimising regulation, which is aligned to the relevant EU competition rules discussed in this section. The next section therefore assumes that the UK insurance industry exists in a Liberal Market, and explores how efficiency fits in as a measure of performance.

2.2 SCP and Efficient Structure Hypothesis

If the UK insurance industry is a liberal market, then the analysis by Barney and Clark (2007) that compares companies that are subject to the Theory of Structure, Conduct and Performance (SCP), versus those that fall under a Resource-Based View (of which the Efficiency Structure Hypothesis is a part), would suggest that the UK Insurance Industry falls under the Resource Based View. The background of both SCP and the Efficient Structure Hypothesis, including how the latter appears to have been built on the former, is discussed in sections 2.2.1 and 2.2.2 below.

\textsuperscript{22}Source: www.canadalife.co.uk/about-us
2.2.1 SCP
The SCP theory was developed by Bain (1956), as part of an effort to understand why some companies outperform others. At a high level, SCP states that a company’s performance is based on market power and drivers, including barriers to entry and regulation. In this paradigm, Efficiency is seen as one measure of performance, but not a driver of it. The SCP Paradigm was summarised concisely by Jedlick & Jumah (2006) (see Figure 2-2 below). Porter (1979, 1981) also appears to draw heavily on SCP in his explanation of the impact that a firm’s ‘market power’ has on its ability to raise prices above a competitive level. If entries into industries where firms are exercising market power are restricted by various barriers, then these performance differences can persist.

Pope and Ma (2008) noted that the Harvard Paradigm provides a conceptual framework from which the market structure–performance relationship can be assessed and has proven to be readily adaptable as a conceptual model of insurance market operations (Swiss Re, 1996). In his presentation of the Paradigm, Porter (1980) identified five forces (characteristics of market structure) that influence a market’s conduct, which in turn determines the market’s performance. Four of the forces can be considered external to the industry: the threat of entry, the threat of substitution, the bargaining power of consumers, and the bargaining power of suppliers. The fifth force, the level of market competition, is conceived of as an internal force and is generically described as the intensity of rivalry among current market competitors. Additionally, Porter (1991) later noted that these dynamics are subject to the influence of regulatory oversight, which may serve as a catalyst (or inhibitor) of innovation in the marketplace.
Pope and Ma (2008) also add that, within the insurance market context, the roles of buyer and supplier of the product are uniquely intertwined. Conceptually speaking, the premiums paid by insurance policyholders are pooled to create a fund from which qualified claims are paid. Therefore, within the insurance context, the insurance policyholders may be conceived of as being both the buyers for the products as well as the suppliers of the necessary capital.
to create a functioning insurance market. The insurance market is traditionally composed of a number of relatively small consumer entities having only weak negotiating power. The same is true in their role as suppliers of capital for the insurance mechanism. A decision on the part of even the largest commercially insured entity to withdraw from the insurance market would have little impact on the total capital available to the market place. Thus, within the context of the Paradigm suppliers and buyers have little actual influence on the industry’s operations. The structural forces that remain to be considered are the level of market competition, the threat of entry, and the threat of substitution.

Although the *Harvard Paradigm* may provide a conceptual framework, Cowling and Waterson (1976) supported the SCP hypothesis by theoretically identifying a positive relationship between the profit–margin ratio (a measure of market performance) and market concentration. This relationship is written formulaically below:

\[
\frac{\pi}{R} = \frac{H}{\eta} (1 + \mu)
\]

(1)

Where:

\(\pi\) is the Market Profit
\(R\) is Market Revenue
\(H\) is the Herfindahl Index of market concentration
\(\eta\) is the price elasticity of demand
\(\mu\) is the weighted sum of conjectural variations.

Thus, Cowling and Waterson (1976) established a theorized positive relationship between market concentration (\(H\)) and profitability (\(\pi /R\)) in Equation (1). Additionally, they identified
a theorized negative relationship between market profitability and the price elasticity of demand ($\eta$).

### 2.2.2 Efficient Structure Hypothesis

As discussed above, a key condition that underpins the SCP paradigm is that entries into industries where firms are exercising market power are restricted by various barriers. So although this arguably applies in – say – an oligopoly that heavily restricts new entrants, the Paradigm is open to challenge in industries that have little or no barriers. For example, the UK Life Insurance industry is currently subject to the EU’s Third Generation Insurance Directive of 1994, whose objective was to remove such barriers by creating a single market for insurance products across Europe via deregulation in the relevant member states (Cummins et al, 1996). In addition, foreign insurance companies have been able to enter the market for many years (e.g. Canada Life started its UK operations in 1903$^{24}$). Similar arguments across other countries and industries led to the development of the second explanation to rival the ‘Market Power’ view discussed in section 2.2.1. Peltzman (1977) also highlights that the ‘Market Power’ view does not take relationships between market share, concentration, and efficiency into consideration.

The alternative view therefore focusses less on market power, and more on the differential ability of some firms to more effectively and efficiently respond to customer needs (Demsetz 1973). Demsetz (1973, 1974) and Peltzman (1977) provided a foundation for this alternative view to the SCP Paradigm by proposing the Efficient Structure hypothesis. This hypothesis suggests that the structure of the market in which a firm operates is also determined by efficiency. In this alternative paradigm, higher profits are earned by relatively

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$^{24}$ Source: https://www.canadalife.co.uk/about-us
more efficient firms, and since concentration is a by-product of efficiency, these profit gains are viewed as economic rents rather than monopoly rents. This explanation was supported by Rumelt (1984), who suggested that if it is costly for less efficient and effective firms to copy more efficient and effective firms, then the superior performance of these latter firms can persist. Foss and Knudsen (2003) noted how this explanation draws heavily on neoclassical price theory.

Wernerfelt (1984) arguably produced the first publication that provided a conceptual framework relating to this alternative view to a firm’s performance, which was titled a “Resource-Based-View”. Independent of the Efficient Structure hypothesis, Wernerfelt (1984) attempted to develop a theory of competitive advantage based on the resources a firm develops or acquires to implement product market strategy as a complement or dual of Porter (1980)’s theory of competitive advantage based on a firm’s product market position. It was called a ‘view’ because Wernerfelt (1984) was simply viewing the same competitive problem described by Porter (1980) from the perspective of the resources a firm controls. Barney (1986) supported Wernerfelt (1984)’s view that it is possible to develop a theory of persistent superior firm performance based on the attributes of the resources a firm controls. However, Barney (1986) moved beyond Wernerfelt (1984) by arguing that such theory can have very different implications than theories of competitive advantage based on the product market positions of firms. Barney (1986) therefore began a shift from the Resource-Based-View to what researchers like Barney and Clark (2007) now call Resource-Based-Theory. The Efficient Structure Hypothesis therefore sits within this Resource-Based framework.
It’s worth noting that the SCP Paradigm recognises the efficiency of firms (as can be seen in Figure 2-2 above). However, under that Paradigm, efficiency appears to be seen as a measure of performance, as opposed to a driver behind that performance. The Resource-Based approach, on the other hand, sees a key role for efficiency as a driver of a firm’s overall performance.

From the perspective of insurance efficiency research, the Efficient Structure Hypothesis laid the groundwork for empirical studies to be conducted across the globe which mainly looked to:

a) quantify the levels of efficiency or efficiency change prevailing in the chosen industries; and

b) explore the drivers behind efficiency in the chosen industries, once quantification had taken place.

The following section explores these empirical studies, and their relevance to the study documented in this thesis.

### 2.3 Empirical Literature Review

An extensive systematic empirical literature review, consisting of publications from peer-reviewed journals for the period 1990-2019, was conducted for the purpose of this study. The start-point of the period was chosen to coincide with the period just before the Third Insurance Directive in 1994, which arguably fully liberalised the insurance industry in the European Union, and is therefore arguably the most relevant period for efficiency studies in this region (including in the UK). The end-point (the beginning of July 2019) was chosen to ensure that the review attempted to cover the most recent published literature at the time of the first draft of this report. Finally, the review was restricted to published and peer-
reviewed work to support the validity of the findings of this study, in the event that they are implemented in practice or are used as the foundation of future empirical literature.

Sections 2.3.1 and 2.3.2 summarise and analyse the results of this detailed review under two broad categories:

- Stage 1: Efficiency Measurement
- Stage 2: (in) Efficiency Drivers.

Section 2.3.3 then reports on a more detailed review of some of the European literature, which is arguably of most relevance given the context of the UK Life Insurance Industry.

2.3.1 Stage 1: Efficiency Measurement

Table 2-1 below provides details of the literature review performed on the Efficiency Measurement aspect of the study. The most common approach (as well as the approach used more in recent published papers such as Eling and Jia (2018) and Karbhari et al. (2018)) used in Stage 1 appears to be the non-parametric Data Envelopment Analysis (DEA) approach. Eling and Luhnen (2010) suggest that the appeal of this approach is the fact that it does not make an assumption about the distribution of the error term in the production or cost function in the same way that a parametric approach like the Stochastic Frontier Analysis (SFA) would require. That said, there are debates in the literature about which approach is the most appropriate, with some authors finding that the choice of approach did not significantly alter the finding (e.g. Fecher et al. (1993)) while the opposite is true in other studies (e.g. Cummins and Zl (1998)). In order to align the methodology with the most common one used in recent literature, but also acknowledge the debate between parametric and non-parametric approaches, this study will use the DEA approach to estimate efficiency scores, and then validate and conduct robustness checks on the output.
using the SFA, which appears to be the most common parametric approach, and also appears to have been used in all UK-focused studies reviewed as part of this study.

There appears to be reasonable consensus about what constitutes insurance inputs to an insurance firm’s production process in the literature; namely: Labour, Business-related services (e.g. office accommodation) and Financial Capital (in the form of Equity Capital and Debt Capital). Labour and Financial Capital appear to be commonly picked as core parts of inputs, with Business related services and the granular elements of Financial Capital being used where available. For UK data, Hardwick and Li (1997) argue that Labour costs make up 80% of operating expenses, while Ward (2002) notes that looking at the granular elements of Financial Capital is problematic because of the existence of mutual organisations that cannot raise equity capital. This study will therefore use Labour and a combined measure of Financial Capital as a minimum. Details of the exact choices are discussed in section 3.

Unlike inputs, there appears to be more debate in the literature about what constitutes insurance outputs. Although a variety of approaches of looking at outputs are used, the majority of studies appear to use the ‘valued-added’ approach, which looks at an insurance firm as primarily providing value-added services to policyholders, consisting mainly of Risk-Pooling and Financial Intermediation services. Since these are intangible outputs, proxies are required to represent them in empirical studies. There are again a variety of proxies used in the literature, but a measure of claims/losses incurred or premiums appears to be commonly used as a proxy for Risk-Pooling, while Invested Assets or Additions to Reserves are used as a proxy for Financial Intermediation. While there does not appear to be criticism against using either of the Financial Intermediation proxies, the use of premiums as an
output is seen as problematic by some authors because it contains an element of price, so is not just representing the risk being pooled (Eling and Luhnen (2010)). The U.S.A literature, which currently dominates research in the area of insurance efficiency, appears to commonly use claims and invested assets as insurance outputs. In the UK, 3 of the 5 studies reviewed use claims as a risk-pooling proxy, with no clear dominant proxy used for Financial Intermediation. This study acknowledges the limitations of using premiums as an output, and will therefore use claims and invested assets as outputs.

These inputs and outputs are then used to measure different types of efficiencies (e.g. cost, profit, revenue). The most recent study to measure any type of efficiency in UK Life Insurance Industry appears to be by Hardwick et al. (2011). This study will therefore look to update the literature by measuring efficiency with more up to date data, and its focus will be on input-oriented cost efficiency, which is defined by Cummins and Xi (2012) as minimising input quantities for a given level of input prices and output quantities. This appears to be the most explored measure of efficiency, and is arguably what practitioners refer to when they discuss improvements to efficiency (i.e. reduction of costs for a given level of output). This will be discussed further in section 3.
Table 2-1: Literature Review for Efficiency Measurement

*Inputs and Outputs are based on the Value-Added Approach, unless stated otherwise*

<p>| Country       | Journal Paper          | Line of Business | Efficiency Type                  | Empirical Method | Inputs                                                                 | Outputs                                                                 |
|---------------|------------------------|------------------|----------------------------------|------------------|                                                                      |                                                                          |
| Angola        | Barros et al. (2014)   | Life, non-life   | Cost                             | DEA              | Labour, Operating Expenses, number of employees, Capital               | Claims, Profits, Premiums, Ceded reinsurance                           |
| Australia     | Worthington and Hurley (2002) | Non-life         | Pure Technical, Scale, Allocative, Cost | DEA              | Labour, information technology, materials (physical capital), debt capital | Premiums, invested assets                                               |
|               | Mahlberg and Url (2003) | Life, non-life   | Technical                         | DEA              | Expenses, cost of capital                                           | Claims, changes in reserves, investment returns, bonuses, returned premiums |
| BRICS countries | Huang and Eling (2013) | Non-life         | Technical, Pure Technical, Scale  | DEA              | Number of employees, Debt Capital, Equity Capital                  | Premiums, Invested Assets                                              |
| Canada        | McIntosh (2016)         | Life, non-life   | Scale                             | Bespoke approach | N/A                                                                   | N/A                                                                     |</p>
<table>
<thead>
<tr>
<th>Country</th>
<th>Journal Paper</th>
<th>Line of Business</th>
<th>Efficiency Type</th>
<th>Empirical Method</th>
<th>Inputs</th>
<th>Outputs</th>
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<tbody>
<tr>
<td></td>
<td>Long Kweh et al. (2014)</td>
<td>Non-life</td>
<td>Cost</td>
<td>DEA</td>
<td>Operating expenses, Debt Capital, Equity Capital</td>
<td>Claims plus additions to reserves, Investment income</td>
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<td></td>
<td>Yao et al. (2007)</td>
<td>Life, non-life</td>
<td>Technical</td>
<td>DEA</td>
<td>Labour, Capital, Claims</td>
<td>Premiums, Investment income</td>
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<td></td>
<td>Bahloul and Bouri (2016)</td>
<td>Non-life</td>
<td>Cost</td>
<td>SFA</td>
<td>Labour, Business Services, Debt Capital, Equity Capital</td>
<td>Claims, Gross Reserves, Ceded Reserves, Invested Assets</td>
</tr>
<tr>
<td></td>
<td>Bahloul et al. (2013)</td>
<td>Non-life</td>
<td>Cost</td>
<td>FFA</td>
<td>Labour, Business Services, Debt Capital, Equity Capital</td>
<td>Claims, Gross Reserves, Ceded Reserves, Invested Assets</td>
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<td></td>
<td>Berger (2003)</td>
<td>Life, non-life</td>
<td>Cost, Scale, Revenue</td>
<td>N/A – Analysis of findings from previous empirical efficiency studies</td>
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<td></td>
<td>Cummins et al. (2017)</td>
<td>Life</td>
<td>N/A – Efficiency is considered in a broader context, as part of the Transmission Mechanism Hypothesis</td>
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<td></td>
<td>Eling and Jia (2018)</td>
<td>Life, Non-life</td>
<td>Technical</td>
<td>DEA</td>
<td>Labour, Capital and Surplus</td>
<td>Total Liabilities, Claims, Invested Assets</td>
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<td>Klotzki et al. (2018)</td>
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<td>Economies of Scale calculated using Houston and Simon (1970) methodology</td>
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<td>Vencappa et al. (2013)</td>
<td>Life, Non-life</td>
<td>Technical, Scale</td>
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<td>Physical Approach: Labour</td>
<td>Physical Approach: Number of units produced</td>
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<td>Fecher et al. (1993)</td>
<td>Life, non-life</td>
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<td>DEA, SFA</td>
<td>Labour, Other expenses</td>
<td>Premiums</td>
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<td>Country</td>
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<td>Line of Business</td>
<td>Efficiency Type</td>
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<td>DEA</td>
<td>Direct costs, Indirect costs</td>
<td>Premiums, Investment income</td>
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<td>Germany</td>
<td>Diboky and Ubl (2007)</td>
<td>Life</td>
<td>Technical, Cost, Allocative</td>
<td>DEA</td>
<td>Labour, Other expenses, Debt Capital, Equity Capital</td>
<td>Premiums, Net income</td>
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<tr>
<td>Germany</td>
<td>Mahlberg and Url (2010)</td>
<td>Life, Non-life</td>
<td>Scale</td>
<td>DEA</td>
<td>Administration and Distribution Costs, Debt Capital, Equity Capital</td>
<td>Claims, Additions to Reserves, Investment Income</td>
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<td>Germany, U.K.</td>
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<td>Life</td>
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<td>Global</td>
<td>Biener et al. (2017)</td>
<td>Life, Non-life</td>
<td>Cost, Scale, Allocative, Technical, Pure Technical, Revenue</td>
<td>DEA</td>
<td>Number of employees, Business services, Equity Capital</td>
<td>Premiums, Claims, Invested Assets</td>
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<td>Country</td>
<td>Journal Paper</td>
<td>Line of Business</td>
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<td>Kader et al. (2010)</td>
<td>Takaful</td>
<td>Cost, Technical, Pure Technical, Scale, Allocative</td>
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<td>Labour, Capital, Total Operating expenses</td>
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<td>DEA</td>
<td>Labour, Capital</td>
<td>Premiums</td>
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<td>Nektarios &amp; Barros</td>
<td>Life, Non-Life</td>
<td>Scale, Pure Technical</td>
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<td>Labour, Non-Labour Cost, Equity Capital</td>
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<td>India</td>
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<td>Technical, Pure Technical</td>
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<td>Claims, Operating Expenses, Agent Commission</td>
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<td>(2011)</td>
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<td>Tone and Sahoo (2005)</td>
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<td>Labour, fixed capital expense, equity capital</td>
<td>Claims/losses incurred, change in reserves, invested assets</td>
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<td>Turchettti and Daraio</td>
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<td>New Business expenses, Overhead expenses, fixed capital, equity capital, debt capital</td>
<td>Claims, Invested assets</td>
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<td></td>
<td>(2001)</td>
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<td>Hirao (2004)</td>
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<td>SFA</td>
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<td>Jeng and Lai (2005)</td>
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<td>Value-Added Approach: Labour, business services, Capital</td>
<td>Value-Added Approach: Number of policies, Total invested assets</td>
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<td>Financial Intermediation Approach: Surplus from previous year, change</td>
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<td>in surplus, expenses, policyholder debt capital</td>
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<td>DEA</td>
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<td>OECD countries</td>
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<td>Cost</td>
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<td>Labour, Capital, Claims</td>
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<td>Claims, Investment Income</td>
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<td>Cummins and Rubio-Misas (2006)</td>
<td>Life, non-Life</td>
<td>Allocative, Cost, Pure Technical, Scale</td>
<td>DEA</td>
<td>Labour, Business Services, Debt Capital, Equity capital</td>
<td>Losses incurred, reinsurance reserves, non-reinsurance reserves, invested assets</td>
</tr>
<tr>
<td></td>
<td>Cummins et al. (2004)</td>
<td>Life, non-Life</td>
<td>Allocative, Cost, Revenue, Technical</td>
<td>DEA</td>
<td>Labour, business services, debt capital, equity capital</td>
<td>Losses incurred</td>
</tr>
<tr>
<td></td>
<td>Fuentes et al. (2001)</td>
<td>Life, non-life</td>
<td>Technical</td>
<td>SFA</td>
<td>Labour</td>
<td>Annual Premiums</td>
</tr>
<tr>
<td></td>
<td>Segovia-Gonzalez et al. (2009)</td>
<td>Life, non-life</td>
<td>Cost</td>
<td>DEA</td>
<td>Number of claims, Cost of Claims, Number of claims when policy taker is guilty</td>
<td>Premiums (Gross of reinsurance), Premiums (Net of reinsurance)</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Biener et al. (2016)</td>
<td>Life, non-life</td>
<td>Cost, Technical, Allocative, Scale, Revenue</td>
<td>DEA</td>
<td>Labour, business services, debt capital, equity capital</td>
<td>Claims, Invested Assets</td>
</tr>
<tr>
<td></td>
<td>Jametti and von Ungern-Sternberg (2005)</td>
<td>Life, non-life</td>
<td>Cost</td>
<td>Bespoke approach that measures efficiency as the Claims: Premium Ratio</td>
<td>N/A – Bespoke approach</td>
<td></td>
</tr>
<tr>
<td>Taiwan</td>
<td>Hao and Chou (2005)</td>
<td>Life</td>
<td>Cost</td>
<td>DFA, SFA</td>
<td>Labour, Physical Capital, Claims</td>
<td>Premiums, Invested Assets</td>
</tr>
<tr>
<td></td>
<td>Hu and Yu (2015)</td>
<td>Life</td>
<td>Cost (Operating)</td>
<td>SFA</td>
<td>Operating Costs, Non-operating Costs</td>
<td>Securities Assets, Other Assets</td>
</tr>
<tr>
<td></td>
<td>Huang et al. (2019)</td>
<td>Life</td>
<td>Technical, Scale</td>
<td>SFA</td>
<td>Number of internal staff, number of field staff, total fixed assets</td>
<td>Premiums, Investment Income</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Line of Business</td>
<td>Efficiency Type</td>
<td>Empirical Method</td>
<td>Inputs</td>
<td>Outputs</td>
</tr>
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<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Wang et al. (2007)</td>
<td>Life, Non-life</td>
<td>Cost, Technical, Allocative</td>
<td>DEA</td>
<td>Labour, Business Services, Equity Capital</td>
<td>Claims, Invested Assets</td>
</tr>
<tr>
<td>Thailand</td>
<td>Yaisawarng et al. (2014)</td>
<td>Non-life</td>
<td>Cost</td>
<td>SFA</td>
<td>Labour, Business Services, Capital</td>
<td>Number of policies, Invested Assets</td>
</tr>
<tr>
<td>U.A.E</td>
<td>Rao et al. (2010)</td>
<td>Life, non-life</td>
<td>Allocative</td>
<td>DEA</td>
<td>Operating expenses, equity and change in reserves</td>
<td>Investment income, liquid asset to total liabilities ratio</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>Bikker and van Leuvensteijn (2008)</td>
<td>Life</td>
<td>Cost</td>
<td>SFA</td>
<td>Physical Approach: Acquisition costs, all other costs</td>
<td>Physical Approach: Premiums, Outstanding number of policies, Total of insured annuities, total of insured capital</td>
</tr>
<tr>
<td>Turkey</td>
<td>Kasman and Turgutlu (2009)</td>
<td>Life, Non-life</td>
<td>Cost, Scale</td>
<td>SFA</td>
<td>Labour, Business Services, Capital</td>
<td>Claims plus additions to reserves, Invested Assets</td>
</tr>
<tr>
<td>U.K.</td>
<td>Hardwick et al. (2011)</td>
<td>Life</td>
<td>Profit</td>
<td>SFA</td>
<td>Labour, Business Services, Equity Capital, Debt Capital</td>
<td>Claims, Additions to reserves</td>
</tr>
<tr>
<td>U.K.</td>
<td>Letza et al. (2001)</td>
<td>Life</td>
<td>Cost</td>
<td>SFA</td>
<td>Inputs and Outputs do not appear to be explicitly described in the journal paper.</td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Line of Business</td>
<td>Efficiency Type</td>
<td>Empirical Method</td>
<td>Inputs</td>
<td>Outputs</td>
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</tr>
<tr>
<td>U.S.</td>
<td>Brockett et al. (2004a)</td>
<td>Non-Life (Property-liability)</td>
<td>n/a</td>
<td>DEA</td>
<td>Financial Intermediation Approach: Previous year’s surplus, change in capital and surplus, underwriting and investment expenses, policyholder-supplied debt capital</td>
<td>Financial Intermediation Approach: Return on Investment, Liquidity assets to liability ratio, solvency score</td>
</tr>
<tr>
<td></td>
<td>Brockett et al. (2004b)</td>
<td>Life (Health)</td>
<td>Technical</td>
<td>DEA</td>
<td>Physical Approach: Premiums, expenses</td>
<td>Physical Approach: Number of outpatient visits, Number of Hospital days, number of member months</td>
</tr>
<tr>
<td></td>
<td>Brockett et al. (2005)</td>
<td>Non-Life (Property-liability)</td>
<td>n/a</td>
<td>DEA</td>
<td>Financial Intermediation Approach: Previous year’s surplus, change in capital and surplus, underwriting and investment expenses, policyholder-supplied debt capital</td>
<td>Financial Intermediation Approach: Return on Investment, Liquidity assets to liability ratio, solvency score</td>
</tr>
<tr>
<td></td>
<td>Choi and Weiss (2005)</td>
<td>Non-Life (Property-liability)</td>
<td>Cost, Revenue</td>
<td>SFA</td>
<td>Labour, materials, equity capital</td>
<td>Invested assets, Losses incurred</td>
</tr>
<tr>
<td></td>
<td>Cummins and Zi (1998)</td>
<td>Life</td>
<td>Allocative, Cost, Technical</td>
<td>DEA, DFA, FDH, SFA</td>
<td>Labour, Financial Capital, materials</td>
<td>Benefit payments (claims), additions to reserves</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Line of Business</td>
<td>Efficiency Type</td>
<td>Empirical Method</td>
<td>Inputs</td>
<td>Outputs</td>
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<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>U.S.</td>
<td>Cummins et al. (1999a)</td>
<td>Life</td>
<td>Cost, Technical, Pure Technical, Scale, Revenue</td>
<td>DEA</td>
<td>Labour, Business Services, Financial Capital</td>
<td>Incurred benefits, additions to reserves</td>
</tr>
<tr>
<td></td>
<td>Cummins et al. (1999b)</td>
<td>Non-Life (Property-liability)</td>
<td>Cost, Technical</td>
<td>DEA</td>
<td>Labour, materials, debt capital, equity capital</td>
<td>Losses incurred, total invested assets</td>
</tr>
<tr>
<td></td>
<td>Cummins et al. (2009)</td>
<td>Non-life</td>
<td>Cost</td>
<td>SFA</td>
<td>Labour, materials, debt capital, equity capital, Total cost</td>
<td>Invested Assets, Investment Income, Turnover, Dollars Surplus Duration</td>
</tr>
<tr>
<td></td>
<td>Cummins et al. (2010)</td>
<td>Life, Non-life</td>
<td>Cost, Revenue, Profit</td>
<td>DEA</td>
<td>Labour, materials, debt capital, equity capital</td>
<td>Claims, Invested Assets</td>
</tr>
<tr>
<td></td>
<td>Erhemjamts (2007)</td>
<td>Life</td>
<td>Technical</td>
<td>DEA</td>
<td>Labour, Business Services, Debt Capital, Equity Capital</td>
<td>Claims, Additions to Reserves</td>
</tr>
<tr>
<td></td>
<td>Grace et al. (2015)</td>
<td>Life, non-life</td>
<td>Cost, Revenue</td>
<td>DEA</td>
<td>Labour, materials, debt capital, equity capital</td>
<td>Claims, Invested Assets</td>
</tr>
<tr>
<td></td>
<td>He et al. (2011)</td>
<td>Non-life</td>
<td>Cost, Revenue</td>
<td>DEA</td>
<td>Labour, materials, equity capital</td>
<td>Claims, Invested Assets</td>
</tr>
<tr>
<td></td>
<td>Huang et al. (2011)</td>
<td>Non-life</td>
<td>Cost, Technical</td>
<td>DEA</td>
<td>Labour, materials, equity capital</td>
<td>Claims, Invested Assets</td>
</tr>
<tr>
<td></td>
<td>Jeng et al. (2007)</td>
<td>Life</td>
<td>Cost, Technical, Allocative</td>
<td>DEA</td>
<td>Value-Added Approach: Labour, business services, Capital</td>
<td>Value-Added Approach: Number of policies, Total invested assets</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Financial Intermediation Approach: Surplus from previous year, change in</td>
<td>Financial Intermediation Approach: Return on Assets,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>surplus, expenses, policyholder debt capital</td>
<td>Three Principal Components of Financial Conditions.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Country</th>
<th>Journal Paper</th>
<th>Line of Business</th>
<th>Efficiency Type</th>
<th>Empirical Method</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Financial Intermediation Approach</em>: policyholder surplus, underwriting and investment expenses, policyholder debt capital</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Park et al. (2009)</td>
<td>Non-life</td>
<td>Cost, Revenue</td>
<td>SFA</td>
<td>Labour, materials, equity capital</td>
<td>Claims, Invested assets</td>
</tr>
<tr>
<td></td>
<td>Pottier (2011)</td>
<td>Life</td>
<td>Cost, Revenue, Profit</td>
<td>DEA</td>
<td>Labour, materials, debt capital, equity capital</td>
<td>Claims, Invested assets</td>
</tr>
<tr>
<td></td>
<td>Shi and Zhang (2011)</td>
<td>Non-life</td>
<td>Cost (X-efficiency)</td>
<td>SFA</td>
<td>Labour, materials, capital</td>
<td>Claims, Invested assets</td>
</tr>
<tr>
<td></td>
<td>Shim (2011a)</td>
<td>Non-life</td>
<td>Cost, Revenue, Pure Technical, Scale, Allocative</td>
<td>DEA</td>
<td>Labour, materials, financial equity capital</td>
<td>Claims, Invested assets</td>
</tr>
<tr>
<td></td>
<td>Shim (2011b)</td>
<td>Non-life</td>
<td>Bespoke approach that measured efficiency as Return of Assets, Return on Equity and Earnings Volatility</td>
<td>N/A – Bespoke approach</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Inputs are unclear from the journal, but it says the approach used is consistent with Choi and Weiss (2005).*
<table>
<thead>
<tr>
<th>Country</th>
<th>Journal Paper</th>
<th>Line of Business</th>
<th>Efficiency Type</th>
<th>Empirical Method</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yuan (2011)</td>
<td>Life, Non-life</td>
<td>Bespoke approach that measured operational (cost) efficiency as the Expense Ratio, and Surplus Utilization efficiency as the Return on Policyholder Surplus.</td>
<td>N/A – Bespoke approach</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.3.2 Stage 2: Efficiency Drivers

Table 2-2 below provides details of the literature review performed on potential efficiency or inefficiency drivers in this study. Although some studies appear to only measure efficiency and how it evolves over time (e.g. Al-Amri et al. (2012)), most studies go on to explore the statistical significance of drivers of efficiency or inefficiency, which is called ‘Stage 2’ in this study. Eling and Luhnen (2010) suggested that the literature on Stage 2 falls into 11 broad determinant categories. This study uses these determinant categories, and proposes two new additional categories that appear to have emerged in recent literature, which the author has called ‘Human Resource and Process Management’, and ‘Product Pricing and Target Markets’. Table 2-2 assigns a category to each study, while Figure 2-3 below provides a summary of the literature by determinant category.

UK studies to date appear to have focussed on either Organisational Form and Corporate Governance, or Distribution Systems. In addition, Financial and Risk Management appears to be one of the categories in the Global literature with potential for further exploration, with only seven previous studies identified so far. This study will therefore look to add to the UK and Global literature by exploring Financial and Risk Management efficiency or inefficiency drivers. The nature of the results from Stage 1 also means that the evolution of efficiency during and after the Global Financial Crisis can also be analysed.

The findings within a category appear to be contextual, and can differ by data set or sample period. For example, a US study by Berger et al. (1997) found that firms using independent agents are not as cost-efficient as those using direct writers. On the other hand, a subsequent US study by Brockett et al. (2005) for a different and more up to date data
sample found that the opposite was true. This suggests that findings are generalizable for the firms in the data sample at a particular point in time.

Figure 2.3: Empirical Literature by Potential Efficiency Determinant

Stage 2 is commonly implemented via a regression approach, and the literature appears to use a variety of approaches (as shown in Table 2.2). These approaches vary in complexity, from the relatively simple Ordinary Least Squares (OLS) approach, to more complex approaches, such as Simar and Wilson (2007)'s truncated bootstrap regression approach. Simar and Wilson (2007) were trying to get round the perceived weaknesses of another commonly used approach in the literature - the Tobit approach, which are summarised by Luhnen (2009) as the use of conventional approaches to inference, which are invalid due to the (downward) bias in the estimated efficiency scores and the complicated and unknown serial correlations among the scores. This study acknowledges this literature debate on
regression techniques, and will base the results on the Tobit approach (after checking for the presence of serial correlations), with the Simar and Wilson’s truncated bootstrap approach and OLS approaches being used as validation tools. A detailed justification of the regression approach and other details of Stage 1 and Stage 2 methodologies are discussed in Chapter 3, with the remainder of this chapter taking a more detailed critical look at the European literature.
### Table 2-2: Literature Review for potential (in)efficiency drivers

<table>
<thead>
<tr>
<th>Country</th>
<th>Journal Paper</th>
<th>Regression Method</th>
<th>Application Category</th>
<th>Selected findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>Barros et al. (2014)</td>
<td>Truncated Bootstrap</td>
<td>General level of efficiency and evolution over time</td>
<td>Older insurance companies with Portuguese origin tend to be more efficient.</td>
</tr>
<tr>
<td>Australia</td>
<td>Worthington and Hurley (2002)</td>
<td>Tobit</td>
<td>General level of efficiency and evolution over time</td>
<td>High levels of allocative inefficiency, leading to low levels of overall efficiency</td>
</tr>
<tr>
<td>Austria</td>
<td>Ennsfellner et al. (2004)</td>
<td>N/A – Comparisons of efficiency scores over time</td>
<td>Regulation Change</td>
<td>Deregulation increased production efficiency</td>
</tr>
<tr>
<td></td>
<td>Mahlberg and Url (2003)</td>
<td>Tobit</td>
<td>Regulation Change</td>
<td>Regulation change led to increased productivity, but considerable inefficiency still remains.</td>
</tr>
<tr>
<td>BRICS countries</td>
<td>Huang and Eling (2013)</td>
<td>Truncated Bootstrap</td>
<td>Intercountry comparisons</td>
<td>Environment affects the efficiency of non-life insurers operating in different countries, which makes it difficult to do cross-country efficiency comparisons. Size, profitability, solvency, and ownership form contribute positively to efficiency in the BRIC countries.</td>
</tr>
<tr>
<td>Canada</td>
<td>McIntosh (2016)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>Scale and Scope Economies</td>
<td>Significant short-run scale economies are found with respect to both the output of new policies and the stock of policies issued.</td>
</tr>
<tr>
<td></td>
<td>Wu et al. (2007)</td>
<td>N/A – no second stage analysis</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>The study used a bespoke approach that combines production performance and investment performance. The industry was highly efficient on the whole.</td>
</tr>
<tr>
<td></td>
<td>Yang (2006)</td>
<td>N/A – no second stage analysis</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>The study (also) used a bespoke approach that combines production performance and investment performance. The industry was (also observed to be) highly efficient on the whole.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
</tr>
<tr>
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</tr>
<tr>
<td>China</td>
<td>Leverty et al. (2009)</td>
<td>Stochastic Frontier Analysis</td>
<td>Regulation Change</td>
<td>There was a structural improvement in efficiency after WTO accession, but geographic and product market restrictions placed on foreign firms reduce these positive effects.</td>
</tr>
<tr>
<td></td>
<td>Long Kweh et al. (2014)</td>
<td>Ordinary Least Squares</td>
<td>Human Resources and Process Management</td>
<td>Insurers have almost monotonically decreasing efficiency for the period from 2006 to 2010. Regression results show that human capital, structural capital and relational capital are significantly and positively related to operating efficiency.</td>
</tr>
<tr>
<td></td>
<td>Yao et al. (2007)</td>
<td>Ordinary Least Squares</td>
<td>General level of efficiency and evolution over time</td>
<td>The Non-life segment of the industry had a slightly higher average efficiency score than the life segment.</td>
</tr>
<tr>
<td>Europe</td>
<td>Bahloul and Bouri (2016)</td>
<td>Ordinary Least Squares</td>
<td>Market Structure</td>
<td>Firms become more efficient and more profitable with a higher concentration ratio and this is in accordance with the structure-conduct-performance (SCP) theory.</td>
</tr>
<tr>
<td></td>
<td>Bahloul et al. (2013)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>After the integration of the CEO power score, not only efficiency scores in each country have changed, but also the order of non-life insurance systems. Also, the CEO power influences the growth of productivity and an optimal power of the CEO can allow the insurance firm to be more productive and more efficient.</td>
</tr>
<tr>
<td></td>
<td>Berger (2003)</td>
<td>N/A – Analysis of findings from previous empirical efficiency studies</td>
<td>Regulation Change</td>
<td>The creation of a single market for the European financial services industry is not likely to bring about strong efficiency gains and that cross-border efficiency barriers may prevent the single market from becoming a reality.</td>
</tr>
<tr>
<td></td>
<td>Cummins et al. (2017)</td>
<td>Ordinary Least Squares</td>
<td>Market Structure</td>
<td>Efficiency is the mechanism through which competition contributes to insurer solvency.</td>
</tr>
<tr>
<td></td>
<td>Diacon et al. (2002)</td>
<td>Tobit</td>
<td>Intercountry comparisons</td>
<td>Evidence of differences of efficiency levels by country, and decreasing levels of technical efficiency over the sampling period.</td>
</tr>
<tr>
<td></td>
<td>Eling and Jia (2018)</td>
<td>Logistic</td>
<td>Financial And Risk Management</td>
<td>Firms that are more technically efficient are less likely to fail.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
</tr>
<tr>
<td>-----------------</td>
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<td>-------------------------------------------------------</td>
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<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Europe</td>
<td>Fenn et al. (2008)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>Market Structure</td>
<td>Most European insurers operating under Increasing Returns to Scale. Size and domestic market share lead to higher levels of cost inefficiency.</td>
</tr>
<tr>
<td></td>
<td>Klotzki et al. (2018)</td>
<td>Ordinary Least Squares</td>
<td>Scale and Scope Economies</td>
<td>Economies of scale exist for all considered markets (Germany, Italy, Spain and the UK) and for most of the considered years. However, the extent of economies of scale varies considerably across countries.</td>
</tr>
<tr>
<td></td>
<td>Vencappa et al. (2013)</td>
<td>N/A – the research calculated results using different output proxies.</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>The choice of output proxies appears to be critical, particularly when exploring long-term productivity trends.</td>
</tr>
<tr>
<td>Finland</td>
<td>Toivanen (1997)</td>
<td>Ordinary Least Squares, Generalised Least Squares</td>
<td>Scale and Scope Economies</td>
<td>There are economies of scope in the production process, and economies of scale at the branch level of a firm, but there are diseconomies of scale at the overall firm level.</td>
</tr>
<tr>
<td>France</td>
<td>Fecher et al. (1993)</td>
<td>Ordinary Least Squares</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>High correlation between parametric and non-parametric efficiency results. A wide dispersion of efficiency scores by company.</td>
</tr>
<tr>
<td>GCC Countries</td>
<td>Al-Amri (2015)</td>
<td>N/A – efficiency score comparisons</td>
<td>Intercountry comparisons</td>
<td>The Takaful insurance industry in GCC is highly technical and pure technical efficient. However, it is moderately cost efficient, and there is a large opportunity for improvement. UAE and Qatar score the highest technical efficiency, while Saudi Arabia and UAE are the most cost efficient among the GCC countries.</td>
</tr>
<tr>
<td></td>
<td>Al-Amri et al. (2012)</td>
<td>N/A – General level of efficiency over time.</td>
<td>General level of efficiency and evolution over time</td>
<td>The insurance industry in the GCC is moderately efficient and there is large room for improvement.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------</td>
<td>------------------------------------</td>
<td>------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>GCC Countries</td>
<td>Alshammari (2018)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>Market Structure</td>
<td>The relationship between competition and efficiency is negative where conventional insurance is concerned and positive only for Takaful. Support for the Quiet Life (QL) hypothesis, where managers in a less competitive market may utilise the market power of their firms and reduce their efforts.</td>
</tr>
<tr>
<td>Germany</td>
<td>Diboky and Ubl (2007)</td>
<td>Truncated Bootstrap</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>Shareholder-owned companies are more efficient than mutual companies.</td>
</tr>
<tr>
<td></td>
<td>Luhnen (2009)</td>
<td>Truncated Bootstrap</td>
<td>Distribution systems</td>
<td>Insurers with a direct distribution channel are more efficient than insurers using either of the two other distribution methods</td>
</tr>
<tr>
<td></td>
<td>Mahlberg and Url (2010)</td>
<td>Truncated Bootstrap</td>
<td>Regulation Change</td>
<td>There is a significant long-term decline for cost efficiency scores.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>Ghana</td>
<td>Alhassan et al. (2013)</td>
<td>Ordinary Least Squares</td>
<td>Market Structure</td>
<td>Support for the Efficient Structure hypothesis for both life and non-life insurance markets. While conflicting results was found for SCP hypothesis in the non-life insurance market, it was rejected in the life insurance market. The life insurance sector has higher levels of efficiency compared to the non-life sector.</td>
</tr>
<tr>
<td>Ghana</td>
<td>Ansah-Adu et al. (2011)</td>
<td>Truncated Bootstrap</td>
<td>Financial And Risk Management</td>
<td>Market share, firm size and the ratio of equity to total invested assets are important determinants of an insurance firm’s efficiency.</td>
</tr>
<tr>
<td>Global</td>
<td>Biener and Eling (2011)</td>
<td>Truncated Bootstrap</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>An increase in size is not necessarily optimal for overall efficiency because technical efficiency is negatively correlated with size. Large and for-profit micro insurers are best able to improve performance when focusing on the use of state-of-the-art technology whereas concentrating on cost-minimizing input combinations is appropriate to address cost inefficiencies for small and non-profit micro insurers. The provision of group policies is more efficient than providing individual policies only.</td>
</tr>
<tr>
<td>Global</td>
<td>Biener et al. (2017)</td>
<td>Generalised Least Squares</td>
<td>Scale and Scope Economies</td>
<td>Large reinsurers are characterized by high cost efficiency, while small reinsurers exhibit superior efficiency only when specialized. Large reinsurers also exhibit revenue scope economies when operating both life and nonlife reinsurance.</td>
</tr>
<tr>
<td>Global</td>
<td>Gaganis et al. (2013)</td>
<td>Ordinary Least Squares</td>
<td>Financial And Risk Management</td>
<td>There is a positive and statistically significant relationship between profit efficiency change and market adjusted stock returns. However, there is no robust evidence that cost efficiency change is associated with stock returns.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>Global</td>
<td>Kader et al. (2010)</td>
<td>Logit</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>Non-executive directors and separating the Chief Executive Officer and Chairman functions do not improve cost efficiency. However, board size, firm size and product specialisation have positive effects on the cost efficiency of Takaful insurers. The regulatory environment is found not to be statistically significant in terms of improving cost efficiency.</td>
</tr>
<tr>
<td></td>
<td>Kader et al. (2014)</td>
<td>Logit</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>Average levels of cost efficiency in takaful insurance markets mirror the efficiency in developed non-life insurance markets. The relative influence of board composition, such as the proportion of non-executive directors on the board, on the cost efficiency of takaful insurers depends on its interaction with other firm-specific characteristics such as board size. Hence, the effect of corporate governance systems on the cost efficiency of takaful insurers can be complicated by various firm-specific factors.</td>
</tr>
<tr>
<td>Greece</td>
<td>Barros et al. (2010)</td>
<td>Truncated Bootstrap</td>
<td>General level of efficiency and evolution over time</td>
<td>The first stage results indicate a decline in efficiency over the sample period, while the second stage results confirm that the competition for market shares is a major driver of efficiency in the Greek insurance industry.</td>
</tr>
<tr>
<td></td>
<td>Nektarios &amp; Barros (2010)</td>
<td>N/A – General level of efficiency over time.</td>
<td>General level of efficiency and evolution over time</td>
<td>Productivity growth varies by sector, with the Life sector being the most productive.</td>
</tr>
<tr>
<td></td>
<td>Noulas et al. (2001)</td>
<td>N/A – General level of efficiency over time.</td>
<td>General level of efficiency and evolution over time</td>
<td>Wide dispersion of efficiencies scores between different companies, but the industry is highly efficient on the whole.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>India</td>
<td>Dutta and Sengupta (2011)</td>
<td>N/A – General level of efficiency over time.</td>
<td>General level of efficiency and evolution over time</td>
<td>Reforms in insurance sector which have led to high competition in the market have increased the technical efficiency of the life insurance industry as a whole, but reduced firms' scale efficiency.</td>
</tr>
<tr>
<td></td>
<td>Tone and Sahoo (2005)</td>
<td>N/A – General level of efficiency over time.</td>
<td>General level of efficiency and evolution over time</td>
<td>An increase in allocative inefficiency after a certain point in the sample period, while cost efficiency started to increase after a later point in the sample period.</td>
</tr>
<tr>
<td>Italy</td>
<td>Cummins et al. (1996)</td>
<td>Tobit</td>
<td>General level of efficiency and evolution over time</td>
<td>Stable efficiency over time (70% – 78% for the industry), with sharp decline in productivity (25% cumulative) due to regression in technology.</td>
</tr>
<tr>
<td></td>
<td>Turchetti and Daraio (2004)</td>
<td>N/A – General level of efficiency over time after regulation change</td>
<td>Regulation Change</td>
<td>Total Factor Productivity and Cost Efficiency increase over time, especially after the EU market regulation changes of 1994.</td>
</tr>
<tr>
<td></td>
<td>Fukuyama and Weber (2001)</td>
<td>N/A – General level of efficiency over time.</td>
<td>General level of efficiency and evolution over time</td>
<td>Productivity and technical efficiency progress over time in Japan.</td>
</tr>
<tr>
<td></td>
<td>Jeng and Lai (2005)</td>
<td>ANOVA, Wilcoxon</td>
<td>Organisational form, Corporate Governance Issues Methodology issues, comparing different techniques or assumptions</td>
<td>Keiretsu firms are more cost efficient than non-specialised independent firms, but deteriorating efficiency for all company types. Value added and financial intermediation approaches to measuring outputs produced different results.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>Malaysia</td>
<td>Baharin and Isa (2013)</td>
<td>N/A – Direct comparison of efficiency scores by organisational form.</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>Takaful has lower cost efficiency than conventional insurance</td>
</tr>
<tr>
<td></td>
<td>Chen et al. (2014)</td>
<td>Tobit, Ordinary Least Squares</td>
<td>Human Resources and Process Management</td>
<td>Intellectual Capital has significantly positive impacts on changes in productivity.</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Barros and Wanke (2014)</td>
<td>Truncated Bootstrap</td>
<td>General level of efficiency and evolution over time</td>
<td>Mozambique insurance companies’ output-increasing potentials are severely constrained, particularly in terms of the ceded reinsurance increasing potentials.</td>
</tr>
<tr>
<td>OECD countries</td>
<td>Rai (1996)</td>
<td>N/A – Intercountry comparisons</td>
<td>Intercountry comparisons</td>
<td>Firms in Finland and France had highest efficiency, while those in the UK had the lowest from the sample chosen. Small firms were more cost-efficient than larger firms, while specialised firms were more cost-efficient than multiproduct firms.</td>
</tr>
<tr>
<td>Portugal</td>
<td>Barros et al. (2005)</td>
<td>Tobit</td>
<td>General level of efficiency and evolution over time</td>
<td>Improvement of technical efficiency over the sampling period</td>
</tr>
<tr>
<td></td>
<td>Brito et al. (2013)</td>
<td>2SLS</td>
<td>Mergers and Acquisitions (M&amp;A)</td>
<td>For the period following the mergers, there is no evidence of an increase in market power through coordinated behaviour, or changes in cost efficiency levels.</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>Akhtar (2018)</td>
<td>Truncated Bootstrap</td>
<td>Product Pricing and Target Markets</td>
<td>Small firms are more efficient than large firms.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Market share and profitability are important determinants of efficiency.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Economies of scale and scope potential for Takaful and large conventional firms.</td>
</tr>
<tr>
<td></td>
<td>Benyoussef and Hemrit (2019)</td>
<td>N/A – Direct comparison of efficiency scores by organisational form.</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>Takaful insurers are relatively more efficient than cooperative insurance companies.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>South Africa</td>
<td>Alhassan and Biekpe (2016)</td>
<td>Ordinary Least Squares</td>
<td>Market Structure</td>
<td>Non-life insurers have high levels of efficiency in cost and low efficiency in profit. There is a positive effect of competition on cost and profit efficiency to validate the “quiet-life” hypothesis which posits that competition improves efficiency.</td>
</tr>
<tr>
<td>South Korea</td>
<td>Park and Park (2015)</td>
<td>Ordinary Least Squares</td>
<td>Human Resources and Process Management</td>
<td>There is a strong positive association between Enterprise Resource Planning (ERP) implementation and the insurers’ efficiency and profitability. However, firms may experience a decrease in efficiency and profitability during the first and second year after ERP implementation.</td>
</tr>
<tr>
<td>Spain</td>
<td>Cummins and Rubio-Misas (2006)</td>
<td>N/A – General level of efficiency over time after regulation change</td>
<td>Regulation Change</td>
<td>Consolidation leads to growth in the Total Factor Productivity index, and increases the number of companies operating with decreasing returns to scale.</td>
</tr>
<tr>
<td>Spain</td>
<td>Cummins et al. (2004)</td>
<td>Frontier Distance</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>In both cost and revenue efficiency, Shareholder-owned companies are more efficient than mutual companies in some segments of the market, while mutual companies are more efficient in other segments. Large mutual companies are also no more or less efficient than Shareholder-owned companies.</td>
</tr>
<tr>
<td>Spain</td>
<td>Fuentes et al. (2001)</td>
<td>N/A – Methodology issues</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>Total Factor Productivity, which is usually estimated using a non-parametric approach, can also be estimated using a parametric frontier approach.</td>
</tr>
<tr>
<td>Spain</td>
<td>Segovia-Gonzalez et al. (2009)</td>
<td>ANOVA</td>
<td>Product Pricing and Target Markets</td>
<td>Revenue efficiency is increased by young policyholders who drive expensive cars, as well as young female policyholders.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Biener et al. (2016)</td>
<td>Truncated Bootstrap</td>
<td>Product Pricing and Target Markets</td>
<td>Diversification strategies directed to the European market are more beneficial for efficiency than those targeting markets outside of Europe.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Jametti and von Ungern-Sternberg (2005)</td>
<td>Consistent Adjusted Least Squares</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>Public insurance providers are about 20% more cost efficient than their private counterparts.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>Taiwan</td>
<td>Hao and Chou (2005)</td>
<td>Generalised Least Squares</td>
<td>General level of efficiency and evolution over time</td>
<td>Market share improves profit efficiency, and there’s no evidence that product diversification improves efficiency.</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Hu and Yu (2015)</td>
<td>2SLS</td>
<td>Financial and Risk Management</td>
<td>There is a positive relation between inefficiency and product risk. At the same time, efficient insurers are seen as taking higher asset risk than inefficient insurers. Well-capitalized insurers operate more efficiently than poorly capitalized insurers.</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Huang et al. (2019)</td>
<td>N/A – Direct comparison between two stages of the production process</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>Twenty-six of Taiwan’s life insurers have a higher average technical efficiency score in the investment stage than in the marketing stage. Scale economies and technical advancements prevail in the two production stages over the sample period.</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Hwang and Kao (2008)</td>
<td>N/A – Methodology issues</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>A bespoke relational model is more reliable in measuring efficiencies than independent models.</td>
</tr>
<tr>
<td></td>
<td>Wang et al. (2007)</td>
<td>Unclear what approach was used.</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>Insider ownership, cash-flow rights, and the presence of outside directors have positive impacts, whereas concentrated ownership, deviation between voting rights and cash-flow rights, board size, and the presence of CEO duality have negative impacts on insurers’ efficiency.</td>
</tr>
<tr>
<td>Thailand</td>
<td>Yaisawarng et al. (2014)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>Product Pricing and Target Markets</td>
<td>The most efficient firms tend to strategically select types of insurance services and underwrite average and small size sum insured per policy to diversify their risks. In addition, they tend to be savvy investors. The opposite holds for the least efficient firms which concentrate in providing labour-intensive, small sum automobile insurance policies or underwrite large coverage policies for fewer policyholders.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>The Netherlands</td>
<td>Bikker and Gorter (2011)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>Organisational form, Corporate Governance Issues</td>
<td>More specialized insurers have lower costs. Thick frontier efficiency estimates point to large cost X-inefficiencies that have moderately decreased over time.</td>
</tr>
<tr>
<td></td>
<td>Bikker and van Leuvensteijn (2008)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>General level of efficiency and evolution over time</td>
<td>Cost efficiency of 72% on average.</td>
</tr>
<tr>
<td>Turkey</td>
<td>Kasman and Turgutlu (2009)</td>
<td>Logistic</td>
<td>Scale and Scope Economies</td>
<td>Economies of scale appear present and significant for any firm size.</td>
</tr>
<tr>
<td>U.A.E</td>
<td>Rao et al. (2010)</td>
<td>N/A – General level of efficiency over time</td>
<td>General level of efficiency and evolution over time</td>
<td>There was a considerable degree of managerial inefficiency among the insurers, with the least efficiency in 2000, and higher efficiency in 2004.</td>
</tr>
<tr>
<td>U.K.</td>
<td>Hardwick and Li (1997)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>General level of efficiency and evolution over time</td>
<td>Cost efficiency of 70% on average. Most firms exhibit Increasing Returns to Scale.</td>
</tr>
<tr>
<td></td>
<td>Hardwick et al. (2011)</td>
<td>Tobit, Generalised Least Squares</td>
<td>Organisational form, corporate governance issues</td>
<td>Board characteristics tend to have little effect on firm efficiency in the UK life insurance market. However, the proportion of non-executive directors on the board exhibits a significant effect on the profit efficiency, once the interaction effects among governance mechanisms are taken into account. The effect can be either positive or negative depending on whether there is separation of the CEO and board chairman positions and whether there is an audit committee.</td>
</tr>
<tr>
<td></td>
<td>Klumpes (2004)</td>
<td>Bespoke approach</td>
<td>Distribution Systems</td>
<td>Firms using direct sales agents are more cost and profit efficient than those using independent sales agents.</td>
</tr>
<tr>
<td></td>
<td>Letza et al. (2001)</td>
<td>Ordinary Least Squares</td>
<td>Organisational form, corporate governance issues</td>
<td>Weak evidence to support the contention that mutual insurers are most cost efficient than proprietary insurers.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td>U.K.</td>
<td>Ward (2002)</td>
<td>Exploratory variables included in the Cost Function</td>
<td>Distribution Systems</td>
<td>Cost efficiencies higher for firms focussing on one type of distribution system than those that use more than one.</td>
</tr>
<tr>
<td></td>
<td>Berger et al. (1997)</td>
<td>Bespoke approach</td>
<td>Distribution Systems</td>
<td>Firms using independent agents are not as cost-efficient as those using direct writers, but are just as profit-efficient.</td>
</tr>
<tr>
<td></td>
<td>Berger et al. (2000)</td>
<td>Bespoke approach</td>
<td>Scale and Scope Economies</td>
<td>Strong support for the strategic focus hypothesis, with the conglomeration hypothesis holding for some types of firms.</td>
</tr>
<tr>
<td></td>
<td>Brockett et al. (2004a)</td>
<td>Logistic</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>Using solvency scores as outputs has a limited impact on efficiency scores</td>
</tr>
<tr>
<td>U.S.</td>
<td>Brockett et al. (2004b)</td>
<td>Bespoke approach</td>
<td>Organisational form, corporate governance issues</td>
<td>Application of a new game-theoretic DEA Model on two types of health organisations: Independent Practice Organisations (IPOs) and Group/Staff Health Maintenance Organisations (HMOs). IPOs found to be more technically efficient than HMOs.</td>
</tr>
<tr>
<td></td>
<td>Brockett et al. (2005)</td>
<td>Range-Adjusted Measure</td>
<td>Organisational form, corporate governance issues</td>
<td>Shareholder-owned companies are less efficient from an inputs perspective, while mutual companies are less efficient from an outputs perspective. Direct systems are less efficient than independent agents.</td>
</tr>
<tr>
<td></td>
<td>Choi and Weiss (2005)</td>
<td>Generalised Method of Moments, H2SLS</td>
<td>Market Structure</td>
<td>Cost-efficient firms charge lower prices and earn higher profits. In addition, profits and prices are higher in revenue-efficient firms.</td>
</tr>
<tr>
<td></td>
<td>Cummins and Nini (2002)</td>
<td>Ordinary Least Squares</td>
<td>Financial and Risk Management</td>
<td>Scope to significantly reduce inputs (e.g. labour costs by 62%) without affecting outputs. Capital found to be used sub-optimally.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
<td>Selected findings</td>
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<tr>
<td></td>
<td>Cummins and Xie (2008)</td>
<td>Ordinary Least Squares</td>
<td>Mergers and Acquisitions (M&amp;A)</td>
<td>Insurers targeted for acquisition achieve greater cost and allocative efficiency gains than firms that have not been involved in an M&amp;A exercise. Acquiring firms achieved more revenue efficiency than non-acquiring firms.</td>
</tr>
<tr>
<td></td>
<td>Cummins and Xie (2013)</td>
<td>Ordinary Least Squares</td>
<td>Scale and Scope Economies</td>
<td>The majority of firms below median size in the industry were operating with increasing returns to scale, and the majority of firms above median size were operating with decreasing returns to scale. However, a significant number of firms in each size decile have achieved constant returns to scale.</td>
</tr>
<tr>
<td></td>
<td>Cummins and Zi (1998)</td>
<td>N/A – Methodology issues</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>Efficiency scores are largely consistent between the different types of econometric approaches, but less consistent between econometric and mathematical programming methods.</td>
</tr>
<tr>
<td>U.S.</td>
<td>Cummins et al. (1999a)</td>
<td>Probit</td>
<td>Mergers and Acquisitions (M&amp;A)</td>
<td>Insurers targeted for acquisition achieve greater efficiency gains than firms that have not been involved in an M&amp;A exercise.</td>
</tr>
<tr>
<td></td>
<td>Cummins et al. (1999b)</td>
<td>ANOVA, Wilcoxon</td>
<td>Organisational form, corporate governance issues</td>
<td>Shareholder-owned companies are more cost-efficient than mutual companies.</td>
</tr>
<tr>
<td></td>
<td>Cummins et al. (2010)</td>
<td>Unclear what approach was used.</td>
<td>Scale and Scope Economies</td>
<td>Property-liability insurers realize cost scope economies, but they are more than offset by revenue scope diseconomies. Life-health insurers realize both cost and revenue scope diseconomies.</td>
</tr>
<tr>
<td></td>
<td>Erhemjamts (2007)</td>
<td>Logistic</td>
<td>Organisational form, corporate governance issues</td>
<td>Shareholder-owned companies are more efficient than mutual companies.</td>
</tr>
<tr>
<td></td>
<td>Grace and Timme (1992)</td>
<td>N/A – comparison of firms’ scale economies</td>
<td>Scale and Scope Economies</td>
<td>Most firms have significant economies of scale, and the largest companies operate with approximate Constant Returns to Scale.</td>
</tr>
<tr>
<td>Country</td>
<td>Journal Paper</td>
<td>Regression Method</td>
<td>Application Category</td>
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<td></td>
<td>Greene and Segal (2004)</td>
<td>Ordinary Least Squares</td>
<td>Organisational form, corporate governance issues</td>
<td>Market share improves profit efficiency, and there’s no evidence that product diversification improves efficiency.</td>
</tr>
<tr>
<td></td>
<td>He et al. (2011)</td>
<td>Logistic</td>
<td>Organisational form, corporate governance issues</td>
<td>Firms with a CEO turnover, especially those with a non-routine turnover, experience more favourable efficiency changes than firms without a CEO turnover.</td>
</tr>
<tr>
<td></td>
<td>Huang et al. (2011)</td>
<td>Truncated Bootstrap</td>
<td>Organisational form, corporate governance issues</td>
<td>There is a significant relationship between efficiency and corporate governance.</td>
</tr>
<tr>
<td>U.S.</td>
<td>Jeng et al. (2007)</td>
<td>Logistic</td>
<td>Methodology issues, comparing different techniques or assumptions Organisational form, corporate governance issues</td>
<td>No efficiency improvements after demutualisation under both the value-added and Financial intermediation approaches to choosing outputs, with the exception of mutually-controlled insurers, which showed improved efficiency under the Financial Intermediation approach.</td>
</tr>
<tr>
<td></td>
<td>Leverty and Grace (2010)</td>
<td>Logistic</td>
<td>Methodology issues, comparing different techniques or assumptions Organisational form, corporate governance issues</td>
<td>Efficient value-added approach firms are less likely to go insolvent, while firms characterized as efficient by the flow approach are generally more likely to fail. The theoretical concern regarding the value-added approach’s use of losses as a measure of output is not validated empirically.</td>
</tr>
<tr>
<td></td>
<td>Park et al. (2009)</td>
<td>Ordinary Least Squares</td>
<td>Distribution Systems</td>
<td>Independent agent insurers are found to be cost inefficient compared to insurers with other distribution systems, but the independent agent insurers have better revenue efficiency compared to their long counterpart, the exclusive agent insurers.</td>
</tr>
</tbody>
</table>

68
<table>
<thead>
<tr>
<th>Country</th>
<th>Journal Paper</th>
<th>Regression Method</th>
<th>Application Category</th>
<th>Selected findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pottier (2011)</td>
<td>Ordinary Least Squares</td>
<td>Regulation Change</td>
<td>Insurer cost efficiency is inversely related to the number of states licensed and directly related to total assets, after controlling for geographic concentration, insolvency risk and other firm-specific characteristics.</td>
</tr>
<tr>
<td></td>
<td>Shi and Zhang (2011)</td>
<td>N/A – Methodology issues</td>
<td>Methodology issues, comparing different techniques or assumptions</td>
<td>Time-variant and time-invariant methods result in significantly different efficiency estimates.</td>
</tr>
<tr>
<td></td>
<td>Shim (2011a)</td>
<td>Ordinary Least Squares</td>
<td>Mergers and Acquisitions (M&amp;A)</td>
<td>M &amp; A activity has the potential to create inefficiencies.</td>
</tr>
<tr>
<td>U.S.</td>
<td>Shim (2011b)</td>
<td>Ordinary Least Squares</td>
<td>Mergers and Acquisitions (M&amp;A)</td>
<td>Acquirers’ financial performance decreases and earnings volatility increases during the gestation period after the M &amp; As. Specialised insurers outperform the product-diversified insurers.</td>
</tr>
<tr>
<td></td>
<td>Weiss (1991)</td>
<td>Ordinary Least Squares</td>
<td>General level of efficiency and evolution over time</td>
<td>Inefficiency of between 12% and 33% of premiums</td>
</tr>
<tr>
<td></td>
<td>Weiss and Choi (2008)</td>
<td>2SLS</td>
<td>Market Structure</td>
<td>Potential to charge higher unit prices through market power in a competitive and loosely regulated business environment. Lower cost and revenue efficiencies in more regulated states than those which are less regulated and more competitive.</td>
</tr>
<tr>
<td></td>
<td>Yuan (2011)</td>
<td>Bespoke Approach</td>
<td>Product Pricing and Target Markets</td>
<td>Firms jointly producing banking and insurance services perform better in their traditional lines of business.</td>
</tr>
</tbody>
</table>
2.3.3 Detailed review of the literature across Europe
This section splits the literature between the pre and post 2000 periods, with supporting or opposing literature from the past or future included in each subsection were relevant. The focus of the detailed literature review is the post-1994 period, as explained further below.

2.3.3.1 1990-2000
Efficiency in the European insurance industry has been widely researched in the recent past, and appears to have been mainly driven by the EU’s Third Generation Insurance Directive of 1994 (Cummins et al, 1996). Cummins et al. (1996) conducted one of the early studies around insurance efficiency in Europe by looking at efficiency and productivity in the Italian insurance industry in the period 1985 to 1993. The study noted the contested nature of insurance inputs and outputs, because they are not tangible, so proxies have to be used. In their study, they used acquisition costs, labour costs, fixed capital (e.g. office costs) and equity capital as inputs. The outputs used were Losses Incurred and Invested Assets. They found no relationship between business mix and technical efficiency, but found that mutual companies are more efficient than stock companies. This second finding is surprising, because the expense preference hypothesis would suggest the opposite, since shareholders have more control on the actions of managers than mutual members (Mester, 1989). They also found that companies that sell both Life and Non-life products are less efficient that specialist companies. This finding challenges the Economies of Scope principle, which refers to lowering the average cost for a firm in producing two or more products (Panzar and Willig, 1981).

Hardwick and Li (1997) conducted a similar study to that of Cummins et al. (1996) in the UK, with a similar time period (1989 – 1993), but focussed on cost efficiency of Life Insurance
companies. Their study findings contradicted those of Cummins et al. (1996), by concluding that organisational form (i.e. mutual versus stock) did not have an impact on efficiency. This was later supported by Letza et al. (2001), who also concluded that there was weak evidence to suggest that mutual companies are more efficient than proprietary ones in the UK Life Insurance market. Hardwick and Li (1997) also found that – on average – larger companies were more efficient than smaller ones. The geographical location of a company in the UK was also seen to have no bearing on its cost efficiency. A direct comparison of this study with Cummins et al. (1996) is made difficult because Hardwick and Li (1997) used SFA to calculate efficiency scores as opposed to DEA, although various studies have suggested use of either approach should not affect the outcome of the analysis. The inputs and outputs are also slightly different, with the UK study using Net Premiums as an output. The findings could be challenged because investment assets or income - a key contributor to insurance earnings – is not included as an output. A later Europe-wide study by Fenn et al (2008) also used a parametric efficiency score approach and excluded assets from the outputs, but they concluded that large companies and those with large market shares were in fact inefficient. This suggested that the efficiency of large companies varied across Europe, with companies in some countries being more efficient than similar companies in other countries. Fenn et al (2008) also used data after the EU’s Third Generation Insurance Directive came into force (1995 – 2001), introducing the possibility of a link between the reduced efficiency of large companies with the introduction of the Directive.

Rees and Kessner (1999) explored the impacts of regulation on insurance efficiency in Europe, by looking at the UK and Germany markets using data from 1992 – 1994, as well as comparing the respective regulatory regimes analytically. The two markets were considered
to be at the extreme ends of the regulation spectrum, with the UK considered to be lightly regulated, while Germany was considered to be heavily regulated. The study concluded that tighter regulation allowed for the survival of higher cost firms. It also suggested that there was more intra-industry efficiency in the UK than in Germany. One potential limitation of this study is that the efficiency scores were not calculated on a consistent basis, given that Premium Income was used as the UK output, whereas the Germany output is the Aggregate Sums Assured.

2.3.3.2 2001-2019
Diacon et al (2002) attempted to build on earlier attempts by Rai (1996) to undertake an international comparison of the efficiency of companies transacting long-term insurance business. Their study focussed on Europe, and included a large data set of 450 companies over the period 1996 – 1999. Their study supported findings by Cummins et al. (1996) that mutual companies are more efficient than proprietary companies. Although they also agreed with Hardwick and Li (1997) that large companies are efficient, they found that very small specialist companies are also among the most efficient, and therefore disagreed with their general conclusion that larger companies are more efficient than smaller ones. In addition, financial security was also found to be a determinant of efficiency. The study produced a detailed country-by-country comparison of efficiency, with the UK, Spain, Sweden and Denmark found to be highly technically efficient. They also found that overall technical efficiency appeared to reduce over the research period. They also speculated that this could have been due to structural changes in the industry as a reaction to the Third Insurance Directive, but it was not explored, and is potentially the subject of future research.
Berger (2003) added to the knowledge on Europe-wide insurance efficiency by looking at the potential efficiency effects of a European Single Market for financial services (including insurance). This study analysed the findings of relevant research papers without conducting an empirical study itself, and concluded that the creation of a single market for the European financial services industry is not likely to bring about strong efficiency gains and that cross-border efficiency barriers may prevent the single market from becoming a reality. This could be supported or challenged by empirical studies around the Third Generation Directive and post implementation of the Solvency II Directive of 2009 (which complemented the Third Generation Insurance Directive, by harmonising solvency regulation across Europe with effect from 1 January 2016\(^{25}\)), which could test the first part of this finding around strong efficiency gains. An empirical study around the Third Generation Directive was conducted by Marlberg and Url (2010), where they investigated the impact of the Single Market on productivity in the German insurance industry in the period 1991 - 2006. They supported the findings by Berger (2003), by finding a long-term decline for cost efficiency scores over the research period. However, they also found that productivity increased during that period, thus suggesting that efficiency does not necessarily lead to increased productivity.

Klumpes (2004) sought to benchmark performance in Financial Services, with a specific focus on the UK Life Insurance industry from 1994 - 1999. In that study, profit and cost efficiency were chosen as performance measures to conduct this benchmarking. This suggests that efficiency is an accepted key performance measure in the insurance industry. The study found that companies that employed their own sales force where more cost and

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profit efficient than those that used Independent Financial Advisors (IFAs), even after controlling for organisational form, firm size and product mix. This is an important finding, since many insurance companies use the IFA distribution route. However, the data period misses the impact of potential organisational restructures that could have occurred in preparation for Solvency II.

Barros et al. (2005) added to the European literature by looking at efficiency and productivity in Portugal’s insurance sector from 1995 – 2001. Their main finding was that some companies experienced productivity growth in the research period, while others experienced a decrease in productivity. These findings could be contested, because investment income and premiums are considered to be inputs – this is inconsistent with many previous studies summarised in Table 2-1. Their literature review also appears to suggest that premiums are an output, and it is not clear why premiums have ended up as an input.

Cummins and Rubio-Misas (2006) explored the role of efficiency in deregulation and consolidation, using the Spanish Insurance industry as an example. The data period (1989 – 1998) spanned the introduction of the EU’s Third Generation Insurance Directive, so captures the deregulation and industry restructuring that came with it. They concluded that small, inefficient and financially underperforming firms were eliminated from the market during this time period due to insolvency or liquidation. They also found that consolidation of the industry created larger companies that are efficient, but experience decreasing returns to scale after a certain point. This suggests that companies looking to merge with or
acquire other companies should consider the efficiency effects of the transaction as part of the decision-making process.

Bikker and Van Leuvensteijn (2008) looked at the relationship with efficiency and competition by focusing on the Dutch Life Insurance Industry in the period 1995 – 2003. They concluded that there was evidence of substantial economies of scale and inefficiencies in the market due to limited competition. Bikker and Gorter (2011) conducted a similar study in a similar time period (1995 – 2005), but turned their focus to the Non-Life part of the Dutch insurance industry and adding an organisational form perspective. Their findings supported the conclusion of substantial economies of scale in the Dutch Insurance industry, and that mutual and proprietary companies both have comparative advantages. They also supported the findings of Cummins et al. (1996) – which used pre-Third Generation Directive data - that specialist companies experience better efficiency than their counterparts with a diversified product pool. A significant question before applying these findings to practice would be whether the findings still hold, in light of significant regulatory developments after 2005 (i.e. Solvency II).

Luhnen (2009) provided an example of how efficiency can be investigated at an industry sub-section level, by investigating the determinants of efficiency and productivity in the Property-Liability section of the Non-Life Insurance industry in Germany from 1995 – 2006. Luhnen (2009) agreed with Hardwick and Li (1997) that larger companies are more efficient than smaller ones (based on UK data). They also support the findings of Klumpes (2004) that using a direct sales force distribution system is more efficient than Independent Financial Advisors (also based on UK data). This suggests that the German and UK Insurance markets
two key insurance markets in Europe – have common determinants of efficiency. The study also waded into the debate about the impact of organisational form on efficiency, and supported the findings by Cummins et al (1996) that mutual companies are more efficient than proprietary ones (and thus contradicted the relevant findings by Hardwick and Li, 1997). This suggests at least one key difference between efficiency determinants in the Germany and UK insurance markets. Their findings also added to earlier contributions that specialist firms are more efficient than diversified ones – there generally appears to be agreement in the literature on the impact of this determinant. Luhnen (2009) also found that higher levels of leverage are associated with better efficiency levels, and that companies that are growing tend to be less efficient than those that are not.

Hardwick et al. (2011) attempted to explore new potential efficiency determinants that had not been previously considered in the literature, by looking at the impact of corporate governance mechanisms on Profit efficiency in the UK Life Insurance industry from 1994 - 2004. They found that - viewed in isolation - board characteristics tended to have little effect on firm efficiency in the UK life insurance market. However, they did find that the proportion of non-executive directors on the board exhibited a significant effect on the profit efficiency, once the interaction effects among governance mechanisms were taken into account. The effect could be either positive or negative depending on whether there was separation of the CEO and board chairman positions and whether there was an audit committee. This introduces a potential link between an organisation’s key personnel, and its efficiency. Bahloul et al. (2013) explored this link further, by looking at the influence of CEO power on a company’s efficiency and productivity. They used Europe-wide Non-Life Insurance industry data from 2002 – 2008, and found that optimal power for the CEO can
allow an insurance company to be more efficient and more productive. However, given the findings by Hardwick et al. (2011) that efficiency in the UK’s life insurance industry is not affected by Board characteristics (which include a prominent role for the CEO, sometimes as Board Chairman), these findings could be challenged at Member-State level. In addition, the data in both studies by Hardwick et al (2011) and Bahloul et al. (2013) precede the period after the global financial crisis (2008 – Present), which arguably had a huge impact on the roles of the Board and the CEO. The findings of both papers might therefore be challenged in light of this.

Biener et al. (2016) appear to have continued on the trajectory of finding new determinants of efficiency that had not been previously explored in European literature, by considering the impact of product diversification strategies on efficiency and productivity on the Swiss Insurance industry. They concluded that diversification strategies directed to the European market are more beneficial compared to those targeting markets outside of Europe. Their study appears to be unique compared to previous studies in a couple of important ways:

1. It starts to refresh the European literature in this area with post-Global Financial Crisis data (the data sample period was 1997 – 2013)
2. It considers efficiency drivers that firms could potentially implement without making significant changes to how they operate their businesses. This is distinct from say, changing the organisational form of a firm from mutual to proprietary.

Although this study is based on one European industry, it builds a foundation upon which studies in other markets can build, in terms of the post Global Financial Crisis period and the exploration of efficiency levers that can be implemented relatively easily. Eling and Jia (2018) appear to build on this foundation, by appearing to be the first European study to
consider Financial and Risk Management determinants of firms across 16 different European countries, using data from 2006 to 2013. Their study concluded that firms that are more technically efficient reduce the risk of business failure. Eling and Jia (2018) therefore appeared to establish a link between Risk Management and Efficiency, and there is potential for this link to be explored further, either by focussing on specific markets within their study, or looking at specific Risk Management levers that have a relationship with efficiency. Cummins et al. (2017) focussed on the potential wider importance of efficiency in the European insurance industry by testing the transmission mechanism hypothesis, which was developed by Schaeck and Cihák (2013). This hypothesis proposes that competition - measured by the Boone (2008) indicator - enhances financial stability, with efficiency being the transmission mechanism through which competition increases financial stability. Their findings supported this hypothesis, so could be important for EU regulators, who – by encouraging competition – could help meet one of their key objectives of financial stability in the industry. However, one could argue that the EU has already done all it can to encourage competition – via the Third Generation Directive – and the findings of this study just serve to support the decision to implement that Directive.

This section concludes by considering the study by Klotzki et al. (2018), who acknowledged the need to reconsider efficiency in the European insurance industry on the back of the low interest rate environment discussed in section 1.1.7 of this study, as well as an apparent increase in acquisition costs, price transparency, cost transparency and competition with banks. Their study focused on Economies of Scale, and they found that – of the four European markets they considered - Germany showed the lowest extent of economies of scale, whereas the UK and particularly Spain and Italy exhibited a considerably stronger
extent of economies of scale. This therefore supports efforts by the UK insurance industry to improve operational efficiency via consolidation, as discussed in section 1.1.8. That said, consolidation tends to create larger organisations, and it is not clear from the study by Klotzki et al. (2018) if firms that attempt to utilise this opportunity of economies of scale via consolidation actually succeed, i.e. whether larger organisations are more efficient than smaller firms, in any of the markets explored. With the literature review chapter complete, the next chapter explores the methodology used in this study in more detail.
Chapter 3: Methodology
3 Methodology

This chapter explains in detail the methodological approach that has been set to meet the aims and research questions of this study, as described in section 1.2. It starts with a detailed discussion on the design of the research, followed by a description and justification of the chosen data. It will then explain the hypotheses that will be tested, as well as outlining how the data and results will be analysed. It will then conclude by discussing ethics considerations in empirical studies that use secondary data.

3.1 Research Philosophy

Underpinning the choice of research methods is the philosophical paradigm under which the research will be conducted. Figure 3-1 below provides a high-level summary of the philosophical spectrum under which Business research can be carried out, according to Saunders et al. (2009). The choice of paradigm is subjective, and will be done through a process of elimination. The elimination steps are discussed in the next few paragraphs.

A key aim of the research – which other aims and objectives depend on – is to investigate the levels of efficiency in the UK insurance industry. This is therefore deductive research, since the level of efficiency already exists and is not going to be constructed. In addition, the research questions are also deductive, as they are looking to test the economic and statistical significance of certain business decisions on the level of efficiency. This conclusion appears to rule out interpretivism as a possible paradigm for this research.
Since this a deductive study, it could be considered under the Positivist paradigm. However, it might be difficult to argue for pure positivism, because that would imply that the findings of the study would be the same under all scenarios and circumstances, which is unlikely for efficiency research. Later sections in this chapter will outline numerous methodological considerations that need to be made before determining the level of efficiency that exists, and it is possible that different methodological considerations could lead to a different outcome – even when using the same set of data. The choice of data set or data period could also have a bearing on the findings. A pure positivist approach is therefore ruled out on this basis. These exclusions leave Realism and Pragmatism as the potential approaches. A more detailed look at these two approaches is summarised in Table 3-1 below.
Table 3-1: Realism versus Pragmatism

<table>
<thead>
<tr>
<th></th>
<th>Realism</th>
<th>Pragmatism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ontology:</strong> the researcher’s view of the nature of reality or being</td>
<td>Objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist).</td>
<td>External, multiple, view chosen to best enable answering of research question.</td>
</tr>
<tr>
<td><strong>Epistemology:</strong> the researcher’s view regarding what constitutes acceptable knowledge</td>
<td>Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts.</td>
<td>Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data.</td>
</tr>
<tr>
<td><strong>Axiology:</strong> the researcher’s view of the role of values in research</td>
<td>Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research.</td>
<td>Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view.</td>
</tr>
<tr>
<td><strong>Data collection techniques most often used</strong></td>
<td>Methods chosen must fit the subject matter, quantitative or qualitative.</td>
<td>Mixed or multiple method designs, quantitative and qualitative.</td>
</tr>
</tbody>
</table>

*Source: Saunders et al. (2009)*

Table 3-1 suggests that pragmatism could be used, since it gives the researcher the freedom to choose research methods that are most suitable to answer the research question. That said, realism (and critical realism in particular) – which appears to give a narrower scope of the possible research methods, would ensure that this research is kept to a similar narrow scope as all the studies discussed in Tables 2-1 and 2-2, which employ a deductive approach to research in this area. This would also support the stated focus of this paper, which aims to contribute more to practice than theory, and therefore intends to intentionally avoid theoretical debates wherever possible. Finally, in the context of insurance efficiency
research, critical realism appears to allow the researcher to make every effort identify and implement valid analytical methods to address different efficiency measurement issues, but also recognise that there is always scope for future improvement in both the conceptual framework and analytical methods.

Based on the discussion above, the choice is to underpin this study on Critical Realism. This consideration acknowledges potential biases of the researcher, which might have contributed to arriving at this conclusion:

1. With a mathematical background, the researcher is partial to following Popper’s Principle of Empirical Falsification, which states that a hypothesis can be tested by empirical experiment (Popper, 1959).

2. The researcher’s current professional role involves managing a key input into Canada Life’s cost base (i.e. Capital). There is therefore an inclination to seek outcomes related to capital via deductive research (e.g. will investing in a certain type of asset improve the company’s capital position?).

Table 3-1 suggests that the research method can be qualitative or quantitative, but must fit the subject matter. In this instance, the subject matter is to conduct an empirical study, which is quantitative by nature. This is consistent with all previous studies listed in Tables 2-1 and 2-2. Details of the quantitative approaches used are discussed in the remainder of this chapter.

### 3.2 Types of Efficiency

The Efficient Structure Hypothesis discussed in section 2.2.2 introduced the concept of efficiency as a driver of competitive advantage. This concept has since evolved into different
types of efficiency, some of which are related. Due to these different types, empirical studies tend to focus on one or two types of efficiency, and explore them in detail. The next step in developing the methodology therefore involves choosing the appropriate type of efficiency to explore. Some of the different types which have been explored in Insurance efficiency literature are briefly described below.

1. Klumpes (2004) defines profit efficiency as the ratio of actual profits to the maximum potential profits that could be earned. Thus, the profit efficiency ratio estimates the proportion of potential profits that are realized. Profit efficiency is also maximized as one, where actual profits equal potential profits.

2. Cummins and Rubio-Misas (2006) define Technical Efficiency, as the ratio of the input usage of a specified firm producing the same output vector to the input usage of a reference set of fully efficient firms (i.e., firms operating on the efficient production frontier). Technical efficiency can be decomposed into pure technical efficiency and scale efficiency.

3. Cummins and Rubio-Misas (2006) also look at Cost Efficiency for a given firm, which they define as the ratio of a given firm's actual costs to the costs of a reference set of fully efficient firms (i.e., firms operating on the efficient cost frontier) with the same output quantities and input prices. Firms achieve cost efficiency by adopting the best practice technology (technical efficiency) and choosing the optimal mix of inputs (allocative efficiency), conditional on outputs and input prices. Cost efficiency is therefore the product of technical and allocative efficiency.

4. Shim (2011a) defined Revenue Efficiency as the ratio of actual revenue to maximum possible revenue for a given level of outputs and inputs.
Cost efficiency has been the focus of the majority of previously published UK studies (see Table 2-1), suggesting that the efficient management of costs is considered to be an important part of the industry. This is not surprising, considering that insurance is not considered to be highly profitable compared to other sectors of the economy, and did not make it onto the list of the 10 most profitable UK sectors of 2018\textsuperscript{26}. It is therefore reasonable to assume that keeping costs down would be a key part of a firm’s business strategy in this industry. In addition, cost efficiency also appears to be the focus of the UK Life Insurance industry in the post-Global Financial Crisis period, based on the discussion in section 1.1.8. It will therefore form the focus of this research project. Once the type of efficiency to investigate is chosen, an approach is then required to measure this efficiency. Different methods exist – these are discussed in section 3.3 below.

### 3.3 Efficiency Methodologies

Eling and Luhnen (2010) discuss the two groups of approaches that can be used to measure efficiency. These are summarised below.

**Econometric approaches**: where a production, cost, revenue, or profit function with a specific structure is specified, and assumptions are made about the distributions of the inefficiency and error terms within the specified function. Examples include:

- Stochastic Frontier Approach (SFA)
- Distribution-Free Approach (DFA)
- Thick Frontier Approach (TFA)
- Flexible Fourier Approach (FFA)

The SFA, DFA and TFA approaches concern the distributional forms of the random error term and the inefficiency term, while the FFA is an example of an approach about the

\textsuperscript{26} Source: https://citywire.co.uk/wealth-manager/news/the-10-most-profitable-sectors-in-the-uk/a1146420
functional form of the efficient frontier. Cummins and Weiss (2002) summarise the differences between the approaches as being around their distributional assumptions of the inefficiency and random error components.

*Mathematical programming approaches*: where a programming approach is used to measure the relationship of outputs to assigned inputs. Eling & Luhnen (2010) highlight that programming approaches put significantly less structure on the specification of the efficient frontier and do not decompose the inefficiency and error terms. Examples include:

- Data Envelopment Analysis (DEA)
- Free Disposal Hull (FDH)
- Range Adjusted Measure (RAM)

The FDH can be seen as a simplified version of the DEA, which is itself a linear programming approach. The RAM is also a variant of the DEA, which aims to give an indication of where input excesses and output deficits lie.

Given the different types of techniques available, it is worth understanding the significance of choosing one technique over another on the findings of the study. Although there is little insurance efficiency literature that comprehensively compares the different approaches, Cummins and Zi (1998) conducted one such study. It focused on a sample of U.S. Insurer data using different econometric and mathematical programming techniques. While they found that different econometric techniques produced reasonably consistent results, there were significant inconsistencies between econometric and mathematical programming approaches. They also found inconsistencies between the DEA and FDH approaches within the mathematical programming category.
As discussed in section 2.3.1, insurance efficiency studies done to date appear to be dominated by mathematical programming approaches in general and DEA in particular. A common theme for the choice of the DEA approach appears to be absence of having to define the distribution of the inefficiency term and a random error term, which is usually required for an econometric approach, and is subjective. Although the SFA approach makes transparent the stochastic nature of the underlying data generation process (DGP) of the variables and their relationship, it is also restrictive in the sense that specific assumptions are made about the functional relationship between inputs and a single output as well as the distribution of the variables and the error term. In comparison, although the underlying DGP of the DEA approach is non-stochastic in nature, the DEA offers the flexibility of data-compatible functional relationship between a set of inputs and a set of outputs.

Although DEA is the dominant methodological approach on the whole, the picture can differ when looking at the sub-groups of efficiency research. For example, the SFA (an econometric approach) has been used in all previous UK-focussed studies discussed in section 2. That said; this study uses the DEA approach for a number of reasons. Firstly, the DEA approach can be used to decompose Cost Efficiency into its various components (i.e. technical and allocative efficiency). This appears to be the first UK study to do this, and will help practitioners to understand the cost-saving capacity at a more granular level. Secondly, the DEA is also more suited to answering the research question on the development of efficiency over time. Thirdly, although most of the previous UK studies appear to be silent on the statistical significance of the error term, one study - by Ward (2002) - assumes that the random error term tends to zero over the period covered by the analysis. This supports
the use of the DEA approach in future UK studies (or at least suggests that it is as valid as econometric approaches in the UK context), which does not separate the random error term from the inefficiency term. Fourthly, choosing this approach will make this UK study consistent with most efficiency studies conducted in other countries on this key methodological aspect. Finally, recent developments in semi-parametric methods (e.g. Simar and Wilson, 2007) can improve the asymptotic properties of the DEA method. While DEA efficiency scores will form the basis of findings from this study, the use of the SFA approach in previous UK studies is also acknowledged. High-level cost efficiency scores using the SFA approach will therefore be produced, in order to compare them against the DEA scores, as well as efficiency scores from previous UK studies.

In the DEA literature, the assumption of returns to scale (RTS) is also critically important for the analysis, as the RTS directly affects the efficient frontier. The literature has considered three scenarios of the RTS:

1. **Constant Returns to Scale** (CRS): This model produces efficiency scores under the key assumption that every firm – or Decision Making Unit (DMU) – in the data sample is operating at optimum scale i.e. scale efficiency = 100% across the board. Under this model, an increase in inputs would result in a proportional increase in outputs. (Charnes et al., 1978). The model is also called ‘CCR’, after the authors Charnes et al. (1978).

2. **Variable Returns to Scale** (VRS): This model is similar to CRS, but removes the optimal scale efficiency restriction, thus allowing a change in inputs to lead to a disproportionate change in outputs (Banker et al., 1984). The model is also called ‘BCC’, after it also derived its name from the authors that popularised the concept.
3. Non-increasing Returns to Scale (NIRS): The specification of NIRS in Cummins and Rubio-Misas (2006) appears to suggest that this is a variation of VRS, which attempts to describe the direction of the variable returns to scale (i.e. whether increasing or decreasing returns to scale exist).

The relationship between the efficient frontiers from these three models can be illustrated diagrammatically, as shown in Figure 3-2 below.

**Figure 3-2: Efficient Frontier Comparison**

If A, B, C, D and E are individual firms, then A, C and E are fully efficient based on the VRS-DEA model, while (B₂, B) is the maximum input reduction that firm B can make without affecting output, and thus also become VRS-efficient. As well as being on the VRS frontier, Firm C is also on the CRS and NIRS frontiers, demonstrating that it is possible for a firm to be efficient under any assumption. That said, Firms A and E provide examples of why it is important to define the efficiency frontier assumption, because while both are VRS-
efficient, neither is CRS-efficient and only Firm E is NIRS efficient. In addition, Firm B would need to reduce inputs even more in this case \((B_1, B)\) to become CRS-efficient, with the efficiency not helped by cutting output towards \(B_3\). Firm A demonstrates the feature of a disproportionate relationship between inputs and outputs, where output can be increased from \(A_1\) to \(A\) without increasing inputs.

This study will use the VRS model, and the choice of the model is influenced by both theory and practice. The VRS model is consistent with Fukuyama (1997)’s argument, that private firms (like UK insurance companies\(^{27}\)) do not set out to get constant returns to scale when making business decisions (i.e. they expect to make a profit after meeting all their financial obligations). Fukuyama (1997) argues that CRS might be socially desirable from a policymaker’s perspective, as it is consistent with zero profits in the long-term, thus passing maximum value to policyholders. The nature of the UK insurance industry (i.e. privately held firms and billions of pounds in annual profits, as discussed in section 1.1) suggests that the VRS model is more appropriate. In addition, the use of CRS would also ignore the fact that some scale inefficiencies are potentially artificial, because some insurance companies that operate as separate legal entities are already part of a bigger group. For example, the SynThesys 10.1 database of UK insurance regulatory returns suggests that Aviva plc was a parent to six legal entities in 2015\(^{28}\). In Aviva plc’s case, any measurement of scale efficiency on their Life Insurance businesses is also complicated by Aviva plc being a broad financial services group that includes non-life insurance, asset management and overseas legal entities\(^{29}\). From an empirical perspective, Hardwick and Li (1997) found that most firms

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\(^{27}\) There does not appear to be any record of a UK insurance company being owned by the State.

\(^{28}\) SynThesys version 10.1, by Standard and Poor’s

\(^{29}\) Source: https://www.aviva.com/
(even some large ones) in the UK Life Insurance Industry exhibit Increasing Returns to Scale, suggesting that a CRS or NIRS assumption is inappropriate. VRS will therefore be used in this study. The next step is to specify the models in more detail. This is discussed in sections 3.4 and 3.5 below.

### 3.4 Specification of the Efficiency Measurement model

As discussed in section 3.2, Cost Efficiency is the product of Technical and Allocative Efficiency. Cummins and Rubio-Misas (2006) also note that under CRS, Technical Efficiency can be further decomposed into Pure Technical Efficiency and Scale Efficiency. This leads to the following formula:

\[
\text{Cost Efficiency} = \text{Pure Technical Efficiency} \times \text{Scale Efficiency} \times \text{Allocative Efficiency}
\]

The first step in specifying the overall model is to set out the formula for Technical Efficiency, and then decompose it into Pure Technical and Scale Efficiency. Finally, Cost Efficiency formula will be set out, and Allocative Efficiency will then be derived as Cost Efficiency/ Technical Efficiency.

Technical Efficiency is measured using an input-oriented distance function that was previously used in this area of research by Cummins and Rubio-Misas (1996), having been introduced by Shepard (1970). The function is given by:

\[
D^t_i(x^s_i, y^s_i) = \sup \left\{ \theta^s_i : \left( \frac{x^s_i}{\theta^s_i}, y^s_i \right) \in V^t_i(y^s_i) \right\} = (\inf \left\{ \theta^s_i : (\theta^s_i x^s_i, y^s_i) \in V^t_i(y^s_i) \right\})^{-1}
\]

(1)

Where:

- \( x^s_i \) is a vector of inputs for Firm i in time period \( s \)
- $y_i^s$ is a vector of outputs for Firm $i$ in time period $s$
- $(x_i^s, y_i^s)$ is the input-output vector that follows from the inputs and outputs defined in the two bullet points above
- For any $y^s \in \mathbb{R}_+^N$, $V_r^s(y_i^s)$ denotes the subset of all input vectors $x^s \in \mathbb{R}_+^K$ which yield at least $y^s$ using a production technology characterised by variable returns to scale, $v$. $K$ is the number of inputs and $N$ is the number of outputs.
- $r = c$ for CRS, $r = v$ for VRS and $r = n$ for NIRS

Cummins and Rubio-Misas (2006) note that when $s$ and $t$ represent the same time period ($s = t$), then the Distance Function in Equation 1 follows Farrell’s (1957) radial measure of input technical efficiency, since the function is the reciprocal of the minimum equi-proportional contraction of the input vector $x_i^t$, given outputs $y_i^t$. Technical Efficiency $TE_r^t(x_i^t, y_i^t)$ is therefore defined as $TE_r^t(x_i^t, y_i^t) = 1/D_r^t(x_i^t, y_i^t)$. Technical Efficiency on the CRS frontier is then estimated for each firm in the sample by solving the following linear programming problem:

$$(D_r^t(x_i^t, y_i^t))^{-1} = TE_r^t(x_i^t, y_i^t) = \min \theta_i^t$$

Subject to:

$$Y_i^t \lambda_i^t \geq y_i^t$$
$$X_i^t \lambda_i^t \leq \theta_i^t x_i^t$$
$$\lambda_i^t \geq 0$$

Where $X_i^t$ is a $K \times I$ input matrix and $Y_i^t$ is an $N \times I$ output matrix for all firms in the sample, $x_i^t$ is a $K \times 1$ input vector while $y_i^t$ is a $N \times 1$ output vector for Firm $i$, $\lambda_i^t$ is an $I \times 1$ production intensity vector, and $I$ is the number of firms in the sample.
Having specified overall technical efficiency, this can then be decomposed into pure technical efficiency and scale efficiency using the following formula:

\[ TE_c^t(x_i^t, y_i^t) = TE_v^t(x_i^t, y_i^t)SE^t(x_i^t, y_i^t) \]  (3)

Where:

\[ TE_v^t(x_i^t, y_i^t) \] is the technical efficiency relative to a VRS frontier (pure technical efficiency) and \( SE^t(x_i^t, y_i^t) \) is the scale efficiency. Pure technical efficiency can be solved using Equation 2, by adding an additional constraint on the intensity vector \( \sum_i \lambda_i = 1 \). A variation of this approach is to make this additional constraint \( \sum_i \lambda_i \leq 1 \). This variation will produce pure technical efficiency relative to an NIRS frontier.

Below are some interpretations of potential findings from the model, as discussed by Cummins and Rubio-Misas (2006):

- If \( SE^t(x_i^t, y_i^t) = 1 \) using the \( \sum_i \lambda_i = 1 \) restriction, then CRS exists.
- If \( SE^t(x_i^t, y_i^t) \neq 1 \) using the \( \sum_i \lambda_i = 1 \) restriction, then VRS exists.
- If \( SE^t(x_i^t, y_i^t) = 1 \) using the \( \sum_i \lambda_i \leq 1 \) restriction, then NIRS, and specifically increasing returns to scale (IRS), are present.
- If \( SE^t(x_i^t, y_i^t) \neq 1 \) using the \( \sum_i \lambda_i \leq 1 \) restriction and NIRS technical efficiency \( > TE_c^t(x_i^t, y_i^t) \), then decreasing returns to scale (DRS) are present.

The next step is to describe the approach for obtaining Cost Efficiency. Cummins and Rubio-Misas (2006) describe a two-step procedure. The first step is to solve the problem:

\[ \min_{x_i^t} \sum_{k=1}^{K} w_{ki}^t x_{ki}^t \]  (4)

Where \( w_i^t \) is the input price vector, and all other terms are as previously defined. This is subject to:
\[ Y^t \lambda_i^t \geq y_i^t \]
\[ X^t \lambda_i^t \leq x_i^t \]
\[ \lambda_i^t \geq 0 \]

The convexity vector constraint works in the same way here as it does for technical efficiency, so the same additional constraints discussed after Equation 3 will be required to obtain VRS and NIRS cost efficiencies. The solution vector from Equation 4 (say \( x_i^t^* \)) is the cost-minimising input vector for input price vector \( w_i^t \) and the output vector \( y_i^t \). The second step is to calculate the ratio:

\[ CE_i^t(x_i^t, y_i^t) = (w_i^t, x_i^t^*)/(w_i^t, x_i^t) \]  

This produces the CRS cost efficiency for firm \( i \).

The primary model specification is now complete, since all efficiency scores can now be obtained. The next subsection briefly describes the SFA approach that will be used to produce alternative cost efficiency results for comparison purpose.

### 3.5 Validation: Specification of the SFA model

The SFA efficiency scores will be calculated using the same data set used in the DEA model, but using a pooled data (as opposed to a panel data) approach. The efficiency scores will be extracted from a Cobb-Douglas Cost Function, which is described in a bit more detail later in this subsection. Section 2.3.1 provides evidence of all previous UK studies appearing to use the SFA method. In addition, the Cobb-Douglas Cost Function was used in two of the previous five UK studies (Hardwick and Li (1997) and Ward (2002)), while another two could have used it (the form of the cost function is unclear in Letza et al. (2001) and Klumpes (2004)). This ensures that the findings using the secondary model are loosely comparable to previous UK studies.
The cost function of each insurance company can be specified as described by Ward (2002):

\[ \ln c = \ln C(y_i, w_k) + \ln \mu_c + \ln e_c \]  

(6)

Where:
- \( c \) is the total cost, which is measured in line with Bahloul et al. (2013) as the sum of total operating expenses, cost of debt capital (i.e. investment income) and cost of equity capital (i.e. net overall income);
- \( y_i \) is a vector of firm outputs;
- \( w_k \) is a vector of input prices;
- \( \ln \mu_c \) is the inefficiency term;
- \( \ln e_c \) is the random error term.

Applying the Cobb-Douglas functional form to equation 6 above produces the following estimable cost function:

\[ \ln C = a + \sum_{i=1}^{i} \beta_1 \ln y_i + \sum_{k=1}^{k} \beta_2 \ln w_k + \ln \mu_c + \ln e_c \]  

(7)

Efficiency scores (EFF) will then be extracted from equation 7 using the Distribution Free Method (which assumes that the random error term averages out to zero over the 2007 - 2015 period), as follows:

\[ EFF_{c,k} = \exp(\ln \mu_c^{\text{min}} - \ln \mu_{c,k}) \]  

(8)
Where $ln \mu_{c,k}$ denotes the time-averages of the inefficiency term for each individual firm from the pooled regression, and $ln \mu_{c}^{min}$ is the minimum of these averages which is associated with the most cost-efficient firm.

With both model specifications complete, the next step is to determine the inputs and outputs that will go into the models – this is discussed in 3.6 and 3.7 below.

### 3.6 Choice of Inputs

The majority of studies described in Table 2-1 identify Labour and Financial Capital as insurance inputs, with a reasonable number identifying a third category named Physical Capital or Business Services & Materials (e.g. rentals, advertising). Financial Capital has often been divided into policyholder-supplied debt capital and financial equity capital (e.g. Klumpes (2004)). This study will use Labour, Physical Capital, Financial Debt Capital and Financial Equity Capital as inputs, which is consistent with three out of five previous UK focussed studies (Ward (2002) consider Labour and Capital more broadly, without the granularity proposed in this study, while Letza et al. (2001) does not specify which inputs and outputs were used), and consistent with many other non-UK studies in Table 2-1. The input prices to go with the chosen inputs are as follows:

- **Cost of Labour**: This is measured as Average Weekly Earnings in the Local Authority where a firm’s registered office is based.

- **Cost of Physical Capital**: This cost will not be measured separately, but assumed to be covered by the cost of labour. While there appears to be an agreement in literature that physical capital or business services costs are any costs that are not directly related to direct labour costs related to delivering services to the policyholders and not financial capital costs, there does not appear to be an agreed
approach in the literature to define this. For example, Cummins et al. (2009) define this as labour costs associated with business services for a sample of U.S data, while Cummins et al. (2010) define this as non-labour related expenses for a different sample of U.S. data. In the two published UK studies in Table 2-1 that explicitly allow for physical capital, Klumpes (2004) does not appear to specify how this is set, while Hardwick et al. (2011) use office rent per square foot in the region where a firm’s office is based (thus associating non-labour related costs with office accommodation costs). For efficiency comparison purposes, varying the cost of labour by region arguably captures the effects of office location too, since some recent industry surveys show office rentals to vary by region, with London being the most expensive too (just like wages)\(^{30}\). In the wider European literature, some authors argue that the cost of Business Services should be considered as a combined variable with the cost of Labour (e.g. Bahloul et al. (2013) and Bahloul and Bouri (2016)). In light of the varied approaches available, the data available for the UK life insurance industry, and given the significance of labour-related costs (which Hardwick and Li (1997) suggested was 80% of total costs in the UK insurance industry), this study will align itself with recent published European literature and not consider the cost of physical capital separately, but instead consider it jointly with the cost of labour.

- **Cost of Financial Capital (referred to in the rest of this paper as the ‘Cost of Capital’):**

This cost will be calculated as the ratio of expected investment income to total invested assets. This approach moves away from traditional industry-wide measures of cost of capital (e.g. as in Hardwick and Li (1997) and Ward (2002)) and is more in line with relatively recent studies (e.g. Cummins et al. (2009) and Hardwick et al.\(^{30}\). Source: http://www.colliers.com/en-gb/uk/insights/offices-rents-map
(2011)), which attempt to proxy the cost at firm level, by considering non-profit policyholders as the main owners of debt capital through the reserves set up from premiums collected, with the investment income from those reserves representing the yield on that debt. In addition, the expected investment income also captures the return expected by shareholders and with-profits policyholders, who are considered to be owners of Equity Capital. The cost of capital definition in this study therefore covers these two types of financial capital.

3.7 Choice of Outputs

There is considerable debate in the literature about the choice of outputs in the insurance industry, due to their intangibility. The first step in choosing the relevant outputs is to choose the output measurement approach. Eling and Luhnen (2010) note the four common output measurement approaches as follows:

- **Intermediation Approach**: This approach views an insurance company as a financial intermediary that manages assets and investments on behalf of policyholders, and pays claims and benefits as and when they fall due.

- **User-Cost Approach**: This approach defines an output as investment return or a claim or benefit that falls below the opportunity cost of funds invested to gain that return or pay the claim or benefit.

- **Value-Added Approach**: This approach defines outputs more broadly as services that contribute significant added value, based on costs that will have been allocated to them. These value-added services to the policyholder can either be classed as *risk-pooling/bearing* (e.g. spreading the financial risk of an unexpected death amongst a number of policyholders), or *financial intermediation* (e.g. investing pension
contributions on behalf of a policyholder). The value-added approach appears to be an enhancement of the intermediation approach discussed above.

- **Physical Approach:** This considers physical measurable metrics (e.g. the number of outstanding policies in Bikker and van Leuvensteijn (2008)) as outputs.

Using the intermediation approach would potentially be sub-optimal, because the role of an insurance company is arguably broader than financial intermediation (Cummins and Weiss, 1998). For example, a claim on a term life insurance policy will be designed to pay out many times more than the premiums paid for that policy. In addition, such product lines produce little in the way of investment gains to contribute to any claims, again due to the relatively small size of the premiums when compared with the corresponding claims. A claim on such a policy is therefore a result of the insurance company offering a service where they collect premiums from a large number of people seeking similar insurance, and pay claims from that pool of collected premiums\(^{31}\). This appears to go beyond financial intermediation. In terms of the empirical literature, there appear to only be nine published papers that use the intermediation approach, and the majority are concentrated in specific countries (e.g. two of the three Canadian papers, and three of the four Japanese papers, use this approach. The remaining four are U.S. papers. See Table 2-1 for details). This approach might therefore be appropriate in markets where insurance is viewed mainly as a financial intermediary. However, the limited use of the approach suggests that its use would require robust justification, especially when it has not previously been used in a particular market such as the U.K.

\(^{31}\) This is based on industry experience of the researcher.
The *User-Cost approach* is worth considering, since it appears to look at efficiency from the perspective of optimally utilising the capital employed. This therefore goes hand-in-hand with capital being a key input in the industry. However, it does not appear to have been used by any published empirical studies in this research area to date, and is likely to be difficult to implement in practice, because the data required when using this approach (e.g. product revenues and opportunity costs) is not always available, and even when it is, is unlikely to be publicly available (Eling and Luhnen, 2010). For this study, a UK insurance firm’s regulatory return is arguably the richest source of data when doing an industry-wide study (this data source is discussed further in section 3.10). A sample regulatory return was reviewed as part of this study\(^\text{32}\) and this demonstrated that any analysis of product revenues can only be done at a very high level (i.e. Life Assurance products versus Pension products, not different variants within these categories) and no data is available for opportunity cost. The user-cost approach could therefore not be employed in this study.

The *Physical approach* is also worth considering, since the physical number of (say) policies, can have a strong correlation with the number customer service staff (and therefore the related wages) required to service them. Some authors (e.g. Cummins et al. (1996), Cummins and Rubio-Misas (2006) and Brito et al. (2013)) actually argue that a Physical Approach (using this example of the number of policies) would constitute an ideal measure of output if the data is available. However, like the User-Cost approach, the data required to implement this approach is also likely to be commercially sensitive, and therefore not in the public domain. The sample UK regulatory return discussed in the previous paragraph again demonstrates that data required to use this approach in the UK Life Insurance context does

not appear to be publicly available. Both this and the User-Cost approach could be employed when comparing the efficiency of different product lines within the same company by an in-house researcher (for example). In terms of the empirical literature, only four previously published papers appear to have used this approach before, none of which are based on the UK Life Insurance Industry (see Table 2-1).

This leaves the value-added approach, which appears to be the most commonly used approach in insurance industry efficiency research (as seen in Table 2-1). It addresses the potential shortcomings of the intermediation approach by taking into account the risk bearing/pooling service that insurance companies provide. It also gets round the issue of data availability that the user-cost and physical approaches face, by being flexible in terms of the data that can be used, thus allowing the most suitable available data to be used. Eling and Luhnen (2010) point out though that wide acceptance and use does not necessarily mean validity. Although there does not appear to be a lot of literature that critically compares the value-added approach with other approaches, a couples of papers appear to have done so, by comparing the value-added approach with the financial intermediation approach, with opposing conclusions.

Brockett et al. (2005) argued the case for the financial intermediation approach, by viewing an insurance company as a financial intermediary where the outputs are:

- **Solvency**, which can be a primary concern for regulators of insurance companies,
- **Claims-paying ability**, which can be a primary concern for policyholders, and
- **Return on Investment (ROI)**, which can be a primary concern for investors
Brockett et al. (2005) argue that an insurance company is less of a production entity, and more of a financial intermediary, and they conclude that an intermediation approach acknowledges that interests of insurance firms, their policyholders and shareholders potentially conflict, and the strategic decision makers for the firm must balance one concern versus another when managing the insurance company. Leverty and Grace (2010) did a similar comparison of the output approaches to that performed by Brockett et al. (2005), but appear to have opposing conclusions. As well as concluding that the theoretical concern regarding the value-added approach’s use of losses as a measure of output is not validated empirically, they brought in a firm’s continued existence into the argument, by concluding that efficient value-added approach firms are less likely to go insolvent, while firms characterized as efficient by the financial intermediation approach are generally more likely to fail.

While this study acknowledges that the wide use of the value-added approach does not necessarily mean it is the best approach, it still intends to use it, on the grounds that:

- the debate of whether or not other methods are more appropriate appears to be in its relative infancy;
- the approach appears to be currently considered as best practice in this area of research, and appears to have been used in all previously published UK studies; and
- the approach is in line with the researcher’s view of an insurance firm, from a practitioner perspective.

Having chosen the output measure approach, the remaining challenge is to measure the value-added services. Since risk-pooling/bearing and financial intermediation services are
intangible, proxies need to be chosen to represent them, and there’s considerable debate in the literature about the appropriate proxies to use. For example, while some published authors have argued that premiums cannot be a measure of output since they also include a margin for the insurer’s profit (e.g. Yuengert (1993)), subsequent published studies have used premiums as a risk-pooling output measure anyway (e.g. Hardwick and Li (1997) and Gaganis et al. (2013)). This study acknowledges the debate on the different proxies that could be used (the variety of which can be seen in Table 2-1), and aims to justify the proxies for outputs chosen for the purpose of this study.

The proxy for risk-pooling in this study will be policyholder claims. As discussed above when ruling out the Intermediation Approach of looking at outputs, the payment of policyholder claims is a good example of an insurance company fulfilling its role as a risk-pooling/risk-bearing provider. In addition, this proxy has been used in this way in a good number of studies before (see Table 2-1), and was used in three of the four UK studies discussed in the literature review that published details of their outputs. A slight modification from previous published UK studies is using aggregate claims data across all product lines. This was done because the regulatory returns appear to have changed since the previous published studies, and currently group products into UK Life, UK Pensions and Overseas (previous studies like Ward (2002) and Hardwick et al. (2011) appear to show a different split of Life, Pensions and Private Health Insurance). Mono-line businesses that have emerged in recent years (e.g. Pension Insurance Corporation) and firms that do not conduct overseas business (who make up the majority) would therefore have a lot of zeros in the data, which would be problematic when applying natural logarithms on them for purposes of efficiency
estimation. In addition, this study is not looking to compare efficiency levels by product line, so does not require this split. Aggregate claims data will therefore be used in this study.

The proxy for financial intermediation in this study will be \textit{Invested Assets}. This proxy appears to have been used extensively for this purpose in the literature, including in at least one of the previous five UK-specific published studies, as can be seen in Table 2-1. This appears to be seen as a reasonable proxy, because an insurance company primarily invests assets on behalf of policyholders, and this measures the assets under management for which financial intermediation or investment decisions must be taken (Cummins et al. (2009)).

The methodology discussed up to this point allows for efficiency scores to be produced. The next step is to formally set out the research questions or hypotheses to be answered using these efficiency scores. This is the subject of 3.8 below.

\subsection*{3.8 Construction of Hypotheses}

The research questions in this study are influenced by some of the issues around efficiency in the UK insurance industry in the post 2008 world from a Financial and Capital Management perspective. They are not meant to be exhaustive, but aim to cover some key areas that will help practitioners to understand the nature of the industry from an efficiency perspective, as part of a wider set of tools in effectively managing their businesses.

As discussed in Section 1, much change has occurred in the industry in the post 2008 period in the name of cutting costs and efficiency. One observation from the data appears to be a consolidation of the market, which has seen the number of insurers reduce over time. Section 1.1.8 also discusses how cost reduction is thought to be a key driver in the
consolidation of the UK Life industry in recent years. In practice, a consolidation would be expected to reduce a firm’s labour costs (a key input, as discussed in section 3.6), which should improve cost efficiency. The aggregation of risks between combined entities might also lead to risk diversification benefits, which would reduce any risk based capital requirements (and thus the associated cost of capital). Hardwick and Li (1997) looked at the impact of the size of an organisation (using premiums as a proxy for size) on cost efficiency in the UK Insurance industry, and concluded that size did not have a statistically significant impact (although the larger companies were more efficient). However, their study was conducted before the implementation of risk-based capital measures discussed above, which arguably increase the potential efficiency of large companies with diverse risks. There is therefore a need to understand if this consolidation activity, which results in larger firms than before, is yielding this expected efficiency improvement outcome from the point of statistical significance. This leads to the first hypothesis:

\[ H_1: \text{Larger UK Life Firms are more cost efficient than smaller UK Life firms} \]

The next hypothesis relates to the use of reinsurance. Reinsurance has grown to become a large global sub-sector of insurance and discussed at length by Cummins and Weiss (2000) and Biener et al. (2017). In the UK, the drive for reinsurance in recent years can arguably be traced to the move towards risk-based capital (i.e. ICAS pre-2016 and Solvency II post-2016 as previously discussed in Section 1.1). By using reinsurance, insurance companies pass on some or all of the risks taken on when writing new business, to another insurer. This can therefore reduce a key insurance input (i.e. capital) without affecting output. Insurers are expected to continue to turn to reinsurance, with the European Life Insurance Back Book
*Management 2017* finding that one of the practical implications of the Solvency II regime has been an increased use of reinsurance. Although the relationship between Reinsurance and efficiency does not appear to have been directly investigated in the published insurance literature, Cummins and Nini (2002) found a statistically significant relationship between high levels of reinsurance and low levels of capital utilisation. Less capital should therefore result in reduced costs associated with raising capital (a key input). It is therefore worth understanding if Reinsurance is a statistically significant driver of cost efficiency.

**H₂: Reinsurance increases the Cost Efficiency of a UK insurance company**

In a similar way to Reinsurance discussed above, insurance companies have also been increasingly using derivatives to manage the Capital input of their business in the aftermath of the financial crisis. Along with Reinsurance, increased use of hedging (one type of derivative) was found by the *European Life Insurance Back Book Management 2017* to be one of the key practical implications of Solvency II. In this situation, insurance companies usually turn to capital markets (usually investment banks) to effectively insure against risks that Reinsurance does not normally cover, e.g. Balance Sheet volatility to interest rates. The nature of the Solvency II Balance Sheet has resulted in increased interest rate volatility, particularly for annuity providers, because under ICAS, the focus was on reducing interest rate volatility by matching asset and liability cashflows. This is still required under Solvency II, but the introduction of the interest rate-sensitive Risk Margin (effectively an additional regulatory capital requirement) onto the Balance Sheet has increased the need to manage the related volatility. That said, managing volatility comes at increased cost (i.e. to compensate the investment bank for taking away the unwanted volatility from the

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33 Solvency II and Current Economic Environment – Impact on Consumers’ by the Institute & Faculty of Actuaries.
insurance company), without necessarily changing the output expected by the policyholder (e.g. single premium products that are currently paying a fixed defined monthly pension to a policyholder). Derivatives could therefore have a negative impact on Cost Efficiency. The impact of derivative usage in the UK Life Insurance industry does not appear to have been previously investigated in the published insurance literature. That said, Hardwick and Adams (1999) found that derivative usage in the UK Insurance industry was positively related to a firm’s size. A negative relationship between derivative use and cost efficiency could therefore help to explain why larger firms do not end up with significantly better cost efficiency than smaller firms (based on findings by Hardwick and Li (1997)). In addition, Hardwick and Adams (1999) found that UK Life insurance companies that made more use of derivatives, made less use of reinsurance. It is therefore important to understand the impact of this capital management tool on efficiency; because it will help practitioners to understand if this tool aids efficiency, and potentially influence the balance between use of reinsurance and derivatives if one tool improves efficiency, and the other does not. That said, data limitations mean only the impact of using or not using derivatives can be explored, and not the extent of the use (which would require data of notional amounts for positions opened in a given year, which is not available in the UK Insurance Industry data, as described by Shiu (2007)).

\[ H_3: \text{Derivative use increases the Cost Efficiency of a UK insurance company} \]

The financial crisis also brought a couple of key capital management metrics of an organisation into sharp focus;

1. the solvency position
2. the level of liquidity

There were key examples of companies failing or needing a bailout during the crisis because they were at risk of insolvency (e.g. AIG in the USA), while others were solvent, but appear to have run into difficulties because of a lack of liquidity (e.g. Northern Rock in the UK\textsuperscript{34}). Although it occurred before the Global Financial Crisis, a UK insurance company called Equitable Life was forced close to new business after failing to have enough liquidity to honour annuity payments (Shiu, 2006). In addition, a firm with a high liquidity ratio is expected to find it easier to rebalance an asset portfolio (which it might need to do in times of crisis) than a firm with a low liquidity ratio. For example, the liquidity could be used to replace a corporate bond that was being used to back annuity payments, but defaulted during a crisis. Some of the regulatory responses since the crisis have therefore focussed on these two aspects, by enhancing both solvency and liquidity regulation (as discussed in section 2.1). As discussed in section 3.6 above, the cost of Capital is a key input into a firm’s operations, so holding more capital than required (and therefore the associated cost), would appear to make a firm more inefficient than before. In addition, the current low investment return environment post 2008 discussed in section 1.1.7 might lead firms to invest in higher return (but more risky) asset classes like Private Equity and Emerging markets Equity for commercial reasons, which would further increase any regulatory risk-based capital. Increased liquidity on the other hand would be expected to reduce costs for a firm, since the associated assets (e.g. cash) are expected to carry less risk (see Figure 1-5), so require less regulatory capital (and thus less cost associated with that capital).

\textsuperscript{34} https://www.economist.com/briefing/2007/10/18/lessons-of-the-fall
Solvency in the insurance industry is commonly measured as the level of free assets a company holds over and above regulatory capital requirements (Shiu, 2006). In the UK Life Insurance industry, reported solvency is based on regulatory rules, which consider solvency as the level of free assets above a risk-based capital buffer that is calculated using rules set by the European regulator post-2016, and UK regulator pre-2016 (as discussed in Section 2).

Liquidity, on the other hand, does not appear to have a universally accepted definition. Shiu (2006) investigated the determinants of liquidity in the UK Life Insurance industry (this appears to be the only empirical study that specifically looked at this industry), and defined liquidity as cash plus marketable securities (bonds and equity shares), with the definition of ‘bond’ not explicitly stated. In practice, the definition could be considered to be too broad, since a large discount in the value of (say) a long-dated corporate bond might be required to make it liquid. A company with limited solvency capacity might therefore not define such a bond as ‘liquid’. The definition of ‘bond’ in this study is therefore restricted to government and government-backed bonds, which are considered risk-free in practice.

The discussion above leads to the following two hypotheses:

\( H_4: \) Higher solvency decreases the Cost Efficiency of a UK insurance company

\( H_5: \) Higher levels of liquidity increase the Cost Efficiency of a UK insurance company

The final hypothesis that will be investigated relates to office location. The data used to assign wages to each company, showed a relatively high proportion of registered offices in Central London throughout the sampling period, starting off at 31%, before peaking at 34% in 2009, and then gradually reducing to 28% by 2015 (see Figure 3-3 below).
Central London appears to be the most expensive location from the perspective of Labour costs (according to ONS data), so this is potentially contributing to cost inefficiencies for the relevant companies (given that Labour is a key input for the industry). Hardwick and Li (1997) tested a similar hypothesis in their study, by comparing the efficiency levels of London-based companies with those of regional-based companies. They did not find a statistically significant difference in the efficiency levels, although London-based companies were less efficient. Technological advances since that study have arguably reduced the costs associated with non-labour-related costs, and thus potentially increasing the significance of labour-related costs in driving efficiency. In addition, these same technological advances may have made it possible for regional companies to operate more efficiently, due to (for example) Broadband internet connections reaching more regional areas than before. The downward trend in Central London registered offices in Figure 3-3 also suggests that moving out of Central London is a tool that companies might be using to improve cost efficiency. There is therefore a need to re-examine the relationship between the office location of an organisation and the efficiency levels. This leads to the following hypothesis:
H₆: A Central London Registered Office reduces the Cost Efficiency of
a UK insurance company

The Regression formula can therefore be set out as follows:

\[ EFF_{it} = \gamma_1 \ln(\text{Premiuns})_{it} + \gamma_2 \text{ReinsuranceRatio}_{it} + \gamma_3 \text{DerivativeUse}_{it} \]
\[ + \gamma_4 \text{FreeAssetRatio}_{it} + \gamma_5 \text{LiquidityRatio}_{it} + \gamma_6 \text{CentralLondon}_{it} \]

Where:

- \( \gamma_x \) is this the co-efficient for hypothesis \( H_x \), and \( i \) denotes a firm at time \( t \)
- \( \ln (\text{Premiuns}) \) is the natural logarithm of total Net Written Premiums (NWP) in a given year, and represents the size of the firm, as in Hardwick and Li (1997)
- \( \text{ReinsuranceRatio} \) represents the extent of reinsurance usage in an organisation, and is represented by the ratio of ceded reinsurance premiums written for the year to total annual gross premiums written, as in Hardwick and Adams (1999)
- \( \text{DerivativeUse} \) is a dummy variable that sets derivative users as 1 and non-derivative users as 0 in a given year, and represents the extent of derivative use in the industry, as described in Shiu (2007).
- \( \text{FreeAssetRatio} \) represents the solvency of an organisation in a given year, and is the ratio of free assets a UK Insurance company holds over the regulatory minimum margin, as a proportion of assets allocated to cover the minimum margin, in line with Shiu (2006) and Hardwick et al. (2011).
- \( \text{LiquidityRatio} \) represents the level of liquidity in an organisation in a given year, and is calculated as the ratio of the sum of cash in hand, Deposits not subject to time
restriction on withdrawal with approved institutions, Bank and approved credit and financial institution deposits, government or government-backed bonds (also known as Approved bonds) and equity shares to total admissible assets. This follows a similar definition as in Shiu (2006), with the exception of strictly defining the types of bonds included.

- \textit{CentralLondon} is a dummy variable that is set to 1 for a company with their registered office in Central London, and zero otherwise. This is a similar approach to the one used by Hardwick and Li (1997) for the same industry.

With the hypotheses now defined; the next step to set out the regression approach to evaluate these hypotheses. This is discussed in section 3.9 below.

### 3.9 Regression Approach

The regression approach to use with DEA efficiency scores is also debated in the insurance efficiency literature, and there appears to be no consensus as to the most appropriate approach to use (see Table 2-2). Some studies have used the censored (Tobit) approach (e.g. Huang et. al (2011)), which aims to account for the fact that the dependent variable (DEA efficiency scores) can only be in the range of 0 and 1, thus getting around the key shortcoming of using an uncensored Ordinary Least Squares (OLS) model that was described by Maddala (1983) as leading to biased parameter estimates since OLS assumes a normal and homoskedastic distribution of the disturbance and the dependent variable. However, recent studies have also employed a new approach designed by Simar and Wilson (2007), which involves a truncated regression of contextual variables on efficiency estimates, which is followed by bootstrapping and re-estimation of the regression coefficients. Simar and Wilson (2007) were trying to get round the perceived weaknesses of the Tobit approach, which is summarised by Luhnen (2009) as the use of conventional approaches to inference,
which are invalid due to complicated and unknown serial correlations among estimated efficiency scores.

Although the use of censored models appears reasonable for cost efficiency scores, some authors have argued against such models. For example, McDonald (2009) argues against both the Tobit approach and the alternative introduced by Simar and Wilson (2007), and instead argues for the use of an OLS approach or variants of it. In terms of the Tobit approach, McDonald (2009) argues that the process of deriving efficiency scores is not itself a censored process. He argues that efficiency scores are fractional data, so using a censored approach is inappropriate. In the case of the method introduced by Simar and Wilson (2007), McDonald (2009) argues that although the method might work for the specific scenario that is covered by Simar and Wilson (2007), it is not robust to departures from that specific scenario. McDonald (2009) also describes Simar and Wilson (2007)’s method as a very complex seven-stage estimation procedure, with double bootstrapping. This arguably contributes to its inflexibility at the implementation stage. However, Simar and Wilson (2011) back up the approach introduced by Simar and Wilson (2007), by comparing Simar and Wilson (2007)’s truncated approach with Banker and Natarajan (2008)’s OLS approach and concluding that the truncated approach was robust, and it was the OLS approach that was in fact suitable in very restricted conditions. This lack of consensus suggests that a study can choose from a wide variety of regression approaches with sufficient justification.

Based on the above discussion, this study picked one method, and justified its use. The method that was chosen is the Tobit approach for panel data, which was chosen for a number of reasons. Firstly, the dataset is in the panel form, that is, variations in the data
arise from two dimensions: cross-sectional and time; and the potential influence of
unobserved, time-invariant individual firm characteristics on the estimation results needs to
be considered (Greene, 2003). Secondly, it takes the censored (0, 1) nature of cost efficiency
scores into consideration. Thirdly, it has been used in a number of relevant previous studies,
as can be seen in Table 2-2, including in recent published literature e.g. Chen et al. (2014),
suggesting that the approach can be used with sufficient justification. Fourthly, it will be
unique in the UK literature to use this approach, and will lead to a UK study being in line
with other recent global literature in using this approach. Finally, it arguably strikes the right
balance between methodological robustness from an academic perspective, and ease of
understanding for non-academic practitioners, who are the intended target audience of this
research.

Whilst the Tobit approach was used to perform the regression analysis of this study, the
Random Effects panel model, Simar and Wilson’s Bootstrapping (2007), and OLS approaches
were used as validation tools. The Random Effects approach was chosen because it emerged
as the recommended approach from a series of standard statistical tests that are described
further in Chapter 4, and supports the use of the Tobit approach, which is a variation of the
Random Effects model. On the other hand, the OLS approach was chosen based on the
arguments in support of it by McDonald (2009) that have been discussed in this section.
Finally, the Simar and Wilson (2007) approach was chosen because it aims to addresses
some of the perceived weaknesses of the Tobit approach, which Simar and Wilson (2007)
describe as the potential bias of the efficiency scores when using the traditional DEA
approach, and the serial correlation of the scores, which has the potential to invalid the
results of the regression stage of the analysis. The approach does not appear to be
appropriate for this study, because Badunenko and Tauchmann (2018) note that the approach was designed to measure technical efficiency using cross-sectional data, whereas this study is exploring cost efficiency using panel data. In addition, this study can only implement the regression part of the Simar and Wilson (2007) approach, with the efficiency scores calculated outside this model, due to the panel nature of the data. However, the results are included alongside OLS results, to provide a comparison of the Tobit results with two cross-sectional regression approaches that have previously been used in the literature.

With the methodology of both stages of this study now fully defined, the next step is to describe the data used as part of implementing this methodology. This data is discussed in Section 3.10 below.

3.10 Data

The inputs and outputs of insurance companies discussed in 3.6 and 3.7 can arguably be found in two main sources of data: Annual Report and Accounts, and Regulatory Returns. A key challenge of using the Accounts is that only companies listed on the Stock Exchange, and/or those that have issued debt to the market (so have an obligation to disclose data to Rating agencies such as Standard & Poor’s) publish their annual accounts. This is a particular challenge for the UK insurance industry, where using such data would exclude significant types of insurance companies, such as Mutual organisations that – by design – are not listed. In addition, some of these organisations do not appear to have any rated external debt in the sample period (e.g. Police Mutual\textsuperscript{35}). It would also exclude significant players in the industry that are wholly-owned subsidiaries of non-UK parents. They will therefore not be listed on any Stock Exchange in their own right, and might not issue debt directly to the markets, so would not need to submit accounts to rating agencies. An example is Canada

\textsuperscript{35} Police Mutual does not appear on UK insurance companies covered by Standard & Poor’s Market Intelligence
Life UK\textsuperscript{36}. That said, publicly available accounts are submitted to rating agencies by some of the larger mutual organisations who now use external debt as a source of raising capital (e.g. Liverpool Victoria\textsuperscript{37}), as well as a large spectrum of listed and unlisted insurance companies, which in total account for around 60\% of Gross Written Premiums\textsuperscript{38}. Such accounts could therefore be used as a data source that represents the UK insurance industry.

Regulatory returns appear to get round some of the shortcomings that are presented by accounting data, since every insurance company is expected to submit these returns (which can also be viewed as accounting data in a format prescribed by the Regulator) and make them publicly available. The data therefore represents the whole industry, with no risk of sampling error. The findings might arguably be more credible too, since – for example – some studies have found that higher leveraged companies are more efficient (e.g. Luhnen, 2009), so using rating agency accounts could be challenged as basing UK insurance efficiency findings on firms that are arguably more efficient than the rest anyway. In addition, regulatory data in the UK provides a single template for all firms to complete. The data is therefore standardised and easy to analyse. The same might not be true for Reports and Accounts, which should be comparable because they are usually based on a single set of rules or guidelines\textsuperscript{39}, but the output is not in template format, so there is likely to be a variety of data outputs and analysis from firm to firm. This study will therefore use Regulatory Returns data.

\footnotesize\textsuperscript{36} Canada Life UK is a wholly owned subsidiary of Great-West Life: https://www.greatwestlifeco.com/.
\footnotesize\textsuperscript{37} Based on Standard & Poor’s Market Intelligence
\footnotesize\textsuperscript{38} Based on Standard & Poor’s Market Intelligence
\footnotesize\textsuperscript{39} For example, there is the Generally Accepted Accounting Practice in the UK (UK GAAP). Source: https://www.icaew.com/technical/financial-reporting/uk-gaap
The main source of data will come from Standard and Poor’s’ *SynThesys*\(^{40}\) database version 10.1, which contains historical empirical data of the whole UK insurance industry’s regulatory returns. This data source has been used in previous published UK studies (most recently by Hardwick et al. (2011)), thus supporting its credibility as well as making this study consistent with previous studies in this key area. That said, an alternative data source with similar information could have been obtained from the credit rating agency A.M Best\(^{41}\).

As a validation check, a regulatory return from an insurer’s website\(^{42}\) was downloaded and cross-checked against what was stored for this company by S&P, and this validation test passed. The secondary data source is the UK’s Office of National Statistics (ONS)\(^{43}\), which will provide Gross Weekly Earnings data needed to calculate the price for labour. There do not appear to be more credible data sources than this one for this purpose, and this data source (or its predecessors) has been used for a similar purpose in previous UK insurance efficiency studies (e.g. Hardwick and Li (1997)). Hardwick et al. (2011) appear to have used a sub-section of ONS wage data (called *Regional Trends*) that was specific to the financial sector, but also allowed for regional variation. This would have arguably been an ideal source for wage data in this study. However, that particular section of ONS data appears to have been discontinued in 2011\(^{44}\), and is therefore not available for a significant period of the sample period. This secondary data source is supported by three supplementary public data sources (i.e. Companies House\(^{45}\), Mutuals Public Register\(^{46}\) and The Financial Services

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\(^{40}\) Further details can be found here:

\(^{41}\) Source: http://www.ambest.com/sales/BIR/default.asp

\(^{42}\) The 2009 submission by Wesleyan Assurance Society:

\(^{43}\) Source: https://www.ons.gov.uk/


\(^{45}\) https://www.gov.uk/government/organisations/companies-house

\(^{46}\) https://www.fca.org.uk/firms/mutuals-public-register
Register\textsuperscript{47}, which help to assign the most appropriate earnings data for each company’s office location in the UK. This office location data was collected manually, by looking at individual company information on the websites of Companies House, the Mutuals Public Register and the Financial Services Register, and recording the most recent office address, as well as previous addresses, where evidence of such addresses exist. If no evidence of previous addresses was available, it was assumed that the firm was based at the same registered office throughout the sample period.

All data sources cover the period 2007 – 2015. Although the exact start of the Global Financial crisis is by nature difficult to pinpoint, the filing of bankruptcy by Lehman Brothers on 15 September 2008\textsuperscript{48} is widely regarded as the event that set the crisis in motion globally, having begun with the collapse of the subprime mortgage market in the United States in 2007, which triggered a recession in that country\textsuperscript{49}. In the UK, the base Bank of England interest rate, which the Bank uses to control monetary policy and inflation (which is itself a measure of the increase in consumer spending power), peaked at 5.75% in September 2007. The first interest rate cut of 0.25% came in December 2007 as consumer confidence waned, and gradually kept falling until it reached 0.25% in December 2016. The first interest rate increase since the crisis came in November 2017, but the base rate – at 0.5% - remained very low\textsuperscript{50}. It could therefore be argued that – just like in the United States - the financial crisis also began to be felt in the UK in 2007. Although there appears to be some debate in the literature about the exact start point, the 2007 start point is supported by some authors in the insurance industry literature (e.g. Berry-Stolzle et al. (2011), Drake et

\textsuperscript{47} https://register.fca.org.uk/
\textsuperscript{48} https://www.investopedia.com/articles/economics/09/lehman-brothers-collapse.asp
\textsuperscript{49} https://www.federalreservehistory.org/essays/subprime_mortgage_crisis
\textsuperscript{50} http://www.propertyinvestmentproject.co.uk/property-statistics/uk-interest-rate-history-graph/
al. (2017) and Gonzalez et al. (2017)), on the basis that the crisis started in the USA with the collapse of the subprime mortgage market. This literature and the discussion above based on industry data and analyses are the basis for choosing 2007 as the start point of the period of investigation in this study. Less judgement was required when choosing the end point of the data period, which has been chosen to capture the longest period since the crisis, given the data available at the point of data collection. As at March 2018 (when data was collected), SynThesys had regulatory returns data up to 2015. This would provide 9 years of industry data, which is slightly shorter than the 11 years in Hardwick et al. (2011)’s UK study, but longer than the periods used by all the other UK-focussed published studies discussed in section 2 (5 years in Hardwick and Li (1997), Letza et. al (2001) and Klumpes (2004), and 8 years in Ward (2002)).

The data was used in both Stage 1 and Stage 2 of the analysis, and was implemented in the ‘STATA/IC version 15.1’ software package. The user-written add-ins that produced the DEA scores and the Simar and Wilson regression analysis are included in Appendices 1 and 3 respectively. Specific data items used from the data sources discussed above are detailed in the Tables 3-2 and 3-3 below.
<table>
<thead>
<tr>
<th>Data Item</th>
<th>Source</th>
<th>Form Name in Source</th>
<th>Name of Data Item in Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Operating Expenses*</td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>40</td>
<td>Expenses Payable (Total Business)</td>
</tr>
<tr>
<td>Cost of Capital (£)*</td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>48</td>
<td>Sum(Assets backing NP liabs: Total (Total Business, column 3), Assets backing WP liabs: Total (Total Business, column 3))</td>
</tr>
<tr>
<td>Policyholder Claims</td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>40</td>
<td>Claims Incurred (Total Business)</td>
</tr>
<tr>
<td>Invested Assets</td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>13</td>
<td>Sum(Total admissible assets (as per line 89) (Total LT), Admissible Assets in excess of market &amp; counterparty limits (Total LT))</td>
</tr>
<tr>
<td>Cost of Capital (%)</td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>48</td>
<td>Sum(Assets backing NP liabs: Total (Total Business, column 3), Assets backing WP liabs: Total (Total Business, column 3)) / Sum(Assets backing NP liabs: Total (Total Business, column 2), Assets backing WP liabs: Total (Total Business, column 2))</td>
</tr>
<tr>
<td>Cost of Labour</td>
<td>Annual Survey of Hours and Earnings (ASHE) (Office of National Statistics)</td>
<td>Table 7.1a</td>
<td>Weekly pay - Gross (£) - For all employee jobs: United Kingdom</td>
</tr>
</tbody>
</table>

*This is only used in the SFA validation test as part of total cost components*
### Table 3-3: Efficiency Regression Data Items

<table>
<thead>
<tr>
<th>Data Item</th>
<th>Source</th>
<th>Form Name in Source</th>
<th>Name of Data Item in Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net Written Premiums</strong></td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>Ratios 7</td>
<td>Net Total Premiums</td>
</tr>
<tr>
<td><strong>Reinsurance Ratio</strong></td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>Ratios 7</td>
<td>(Gross Total Premiums – Net Total Premiums)/Gross Total Premiums</td>
</tr>
<tr>
<td><strong>Derivative Use</strong></td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>13</td>
<td>IF {OR(Other investments: Rights under derivative contracts (Total LT), Other investments: Rights under derivative contracts (Total OLT))&gt;0,1,0}</td>
</tr>
<tr>
<td><strong>Free Asset Ratio</strong></td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>2</td>
<td>Excess (deficiency) of capital resources to cover LT business CRR (13-41) / Capital resources to cover LT business capital resources requirement (11+12)</td>
</tr>
<tr>
<td><strong>Liquidity Ratio</strong></td>
<td>Regulatory Returns (SynThesys Life)</td>
<td>13</td>
<td>Sum{Other investments: Equity shares, Other investments: Fixed interest securities – approved, Other investments: Variable interest securities – approved, Other investments: Bank &amp; approved credit &amp; financial inst deposits &lt;= 1 month, Other investments: Bank &amp; approved credit &amp; financial inst deposits &gt; 1 month, Other assets: Deposits not subject to time restriction on withdrawal, Other assets: Cash in hand}) / Sum(Total admissible assets (as per line 89) (Total LT), Admissible Assets in excess of market &amp; counterparty limits (Total LT))</td>
</tr>
<tr>
<td><strong>Central London</strong></td>
<td>Office Locations and Salary Data (Compiled manually for this research – See section 4)</td>
<td>N/A</td>
<td>IF (Central London, 1,0)</td>
</tr>
</tbody>
</table>
With the outline of the data to be used now complete, the next section discusses ethics associated with this data collection, and the study as a whole.

3.11 Ethics Discussion
Ethics are defined by Bulmer (1992) as a matter of principled sensitivity to the rights of others. This ethics section will look at key ethical issues of research in general, how they could affect this study, and potential solutions or mitigation techniques to those issues.

3.11.1 Fundamental Issues for Ethical Research
As a minimum, this study meets the guidelines of the University of Hertfordshire’s Ethics Approval process, which stipulates that Ethics Approval is not required for a study such as this, where only secondary and publicly available data is used. However, Bryman and Bell (2007) suggest that university ethics policies tend to be written in abstract terms, and mainly designed to prevent misconduct. Other ethics codes have therefore also been consulted as part of this research, to expand on any points that might only be implicit in the University of Hertfordshire’s Ethics Approval process.

This section will discuss fundamental issues of ethical research, and splits these issues into five categories as outlined by the University of Worcester.

1. Research must be justified
The ESRC Framework for research ethics (2015) states that research should be worthwhile and provide value that outweighs any risk or harm.

52 Source: https://www2.worc.ac.uk/researchportal/735.htm
A literature review is a key part of this justification, since it is used to identify a gap in the literature, which the research attempts to fill. Iphofen (2011) looks at the ethical perspective of a literature review, by noting that research must demonstrate the ways in which it builds upon or adds to existing research findings. The BERA ethics guidelines (2011) add that it is also ethical to properly cite other people’s literature that is used as part of this process.

Justification of the research conducted in this study is contained in Chapter 2, where a detailed literature review highlighted the contribution to empirical literature and practice that this study is aiming to achieve.

2. **Informed consent** must be given by participants

The Academy of Management Code of Ethics (2006) specifically mentions that a researcher should seek informed consent from participants, in language that the participant understands, documenting all relevant decisions along the way.

All of the data used in this study is secondary and publicly available data, so the issue of informed consent does not arise. That said, this study has a responsibility to the organisations in the data sample, so will not be reporting any information or results that would individually show them in a bad light. For example, even though efficiency scores will be produced for each individual firm in each year from 2007 – 2015 (which show some firms with cost efficiency that is considerably lower than others), these individual efficiency scores by firm will not be included in this report, but instead include summary data for the whole industry.

3. **Participation in research must be voluntary**
Voluntary participation in research is closely linked to informed consent. BERA guidelines (2011) actually cover the two concepts together as voluntary informed consent, recognising that informed consent can arguably not be separated from voluntary participation. Saunders, Lewis & Thornhill (2009) also discuss the voluntary nature of participation and the right to withdraw partially or completely from the process. It could be argued that the issue of voluntary participation does not apply to publicly available data. However, this further highlights the need to use the subsequent results produced by the study in a way that respects the participants in the secondary data.

4. **Confidentiality must be ensured**

As an actuary, the researcher is expected to comply with the Actuaries Code, which expects data users to respect the privacy of organisations. This is again linked to 2 and 3 above, and emphasises the need to avoid calling out individual firms’ efficiency scores. The only information related to each firm that will be disclosed, is the registered office locations used as part of this study. However, as well as being a matter of public record that has not been computed as part of this study, an office location does not in itself say anything about a firm’s efficiency performance or indeed performance on any measure. On the other hand, disclosure is important for the purpose of this study, because this is data that was manually collected as part of this study, and not obtained from a database that has been previously used in the literature such as SynThesys. It is therefore necessary to present the results of this data collection, so it can be open to challenge where applicable.
5. Participants and the researcher(s) should **not come to any harm** during the research. BERA guidelines (2011) and the BPS Ethics Code (2009) cover this point of harm in detail when relating to participants of primary data collection. Although there are arguably fewer considerations at an individual level when secondary data is used, some fundamental key points are still relevant. For example, The Actuaries Code expects the researcher to speak up to the relevant authorities if there is reasonable cause to believe there has been unlawful, unethical or improper behaviour. In this research context, this would apply to anyone associated with this research, including secondary contacts or the researcher’s employer. As discussed in earlier points of this section, the findings will be presented in a way that does not harm the reputations or organisations of either the data owners, or the businesses contained in the data. Iphofen (2011) also suggests that disseminating research findings can itself lead to ethical issues. For example, industry participants might question why the research only looks at the empirical aspect of cost efficiency, without getting the views of industry practitioners on the empirical results. To mitigate these issues at dissemination, the scope of the research, and the underpinning theories have been carefully defined.

The personal safety of the researcher as a result of conducting this research has also been considered, and the conclusion is the risk is very low, due – for example - to the industry-wide nature of the research, whose findings are not focussed on specific individuals, or specific organisations.

**3.11.2 Other Ethics Considerations**

Additional considerations relevant to this study, which may be considered to be in addition to, or implicit in the issues discussed in 3.11.1 include:

*Disclosure of sponsors and biases*
BERA guidelines (2011) discuss the role of sponsors of research, and how important it is to have written agreements in this case. Any conflict of interest that arises should be disclosed. In the case of this study, the researcher’s employer partly funded tuition fees for the duration of this study. That said, this employer is only one of several in the data set, and their key driver for contributing to the tuition was the researcher’s career development, in line with the firm’s policy to support business-related further education. There has therefore been no influence by the employer in any part of this study.

Data handling and access through technology
ESRC Framework for research ethics (2015) discusses how researchers need to consider the ethical issues which arise, for example, in the interpretation of anonymity, and whether participants would consider data in the public domain to be private. The meaning of informed consent in this context and the important issue of what permissions a researcher has over the data supplied by the data producer therefore needs to be considered. All firm-specific data has been collected from regulatory returns, which firms have themselves made regularly available on their websites. It is therefore reasonable to assume that the issue of anonymity or consideration of this data as private does not arise.

With regards to data handling, BERA guidelines (2011) talk about how researchers must comply with the legal requirements in relation to the storage and use of personal data as set down by the Data Protection Act (1998) and any subsequent similar acts. No personal data has been collected as part of this study, so issues around Data Protection are unlikely to be relevant. That said, all research data has been securely stored on a password-protected

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computer, to help ensure that compliance with the Data Protection Act is done in spirit, even though there does not appear to be a legal requirement to do so.

With the methodology and data now defined, Chapter 4 provides results of the data analysis and the calculations done using the methodology and data described in this chapter.
Chapter 4: Results
4 Results

4.1 Secondary Data Analysis

4.1.1 Office Location Data

The results section begins with presenting the Office Location and Earnings data collected for this study. Table 4-1 provides details of the Registered Office location data. As discussed in section 3.10, this office location data was collected manually, by looking at individual company information on the websites of Companies House, the Mutuals Public Register and the Financial Services Register, and recording the most recent office address, as well as previous addresses, where evidence of such addresses exist.

Although the data is comprehensive and considered robust enough to use for the purpose of this study, it does have a few limitations. Firstly, the Mutuals Public Register and the Financial Services Register to do not appear to offer the same depth of historical registered office address data that can be found on the Companies House website. In this instance, it was assumed that the firm was based at the same registered office throughout the sample period. Some firms on these registers might therefore have inaccurate historical office location data. That said, this is considered to be a minor limitation, because only 35 of the 171 legal entities in the raw data sample had data sourced from either the Mutuals Public Register or the Financial Services Register, and the assumption would be correct for some of these 35 firms. Secondly, the registered office location might not necessarily be where the majority of a firm’s operations take place. For example, the registered office of Legal and General Assurance was in Central London throughout the data sample, but the bulk of their operations appear to have been based in Kingswood (Surrey, UK) in this period. This could

therefore lead to some firms getting incorrect efficiency scores assigned to them, and could also affect the overall level of efficiency in the industry. While this limitation is acknowledged, the chosen approach is still considered to be better than the alternative that has been used in some previous UK studies, which implicitly assume that all firms are based in one geographical location, due to assigning the same labour cost to all firms. Table 4-2 will demonstrate that earnings can vary significantly by office location, and this supports the argument to allow earnings to vary by office location. In addition, the most recently published U.K. study in this area by Hardwick et al. (2011) allows for the geographical differentiation, so this study would be in line with that.

This office location data is then used to map it to the appropriate earnings data to use as the cost of labour in the efficiency measurement calculation. This is discussed in 4.1.2 below.
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4.1.2 Earnings Data

Table 4-2 includes the earnings data collected from the Office of National Statistics (ONS), which has been mapped to the office location data in Table 4-1. While this data comes from a credible source that has been used in previous U.K studies in this area, some limitations are acknowledged. As discussed in Section 3.10, Hardwick et al. (2011) appear to have used a sub-section of ONS wage data (called *Regional Trends*) that was specific to the financial sector, but also allowed for regional variation. This would have arguably been an ideal source for wage data in this study. However, that particular section of ONS data appears to have been discontinued in 2011\(^\text{55}\), and is therefore not available for a significant period of the sample period. The data used is therefore considered to be the most appropriate data available. In addition, earnings data is by local authority, and not strictly by postal town.

Some office location earnings might therefore reflect a wider geographical area than just the postal town in question. For example, Borehamwood and Potters Bar both come under the Hertsmere local authority. That said, the data provides valuable information about the variety of earnings data by geographical location, and it is clear to see from Table 4-2 that Central London earnings are much higher than in other areas, suggesting that it is worth investigating if the Central London office location is contributing to inefficiency. Having discussed the supplementary data used in this study, Section 4.2 incorporates this data into the main data set, and begins to draw out some findings from this study.

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<td>704.7</td>
<td>702.8</td>
<td>709.5</td>
<td>694.7</td>
<td>663.4</td>
<td>662.7</td>
<td>645.8</td>
<td>624.2</td>
<td>643.2</td>
</tr>
<tr>
<td>Wakefield</td>
<td>Wakefield</td>
<td>460.1</td>
<td>447.8</td>
<td>466.4</td>
<td>435.7</td>
<td>438.2</td>
<td>430.3</td>
<td>405.3</td>
<td>414.2</td>
<td>424.8</td>
</tr>
<tr>
<td>Wembley</td>
<td>Brent</td>
<td>556.9</td>
<td>528</td>
<td>525.7</td>
<td>485.8</td>
<td>477.9</td>
<td>473.9</td>
<td>496.9</td>
<td>480.8</td>
<td>463.1</td>
</tr>
<tr>
<td>West Malling</td>
<td>Tonbridge and Malling</td>
<td>501.5</td>
<td>492.7</td>
<td>480.3</td>
<td>490.8</td>
<td>467.6</td>
<td>470.5</td>
<td>465.8</td>
<td>476.1</td>
<td>426.1</td>
</tr>
<tr>
<td>Wimbledon</td>
<td>Merton</td>
<td>495.4</td>
<td>498.2</td>
<td>489.1</td>
<td>509</td>
<td>515.8</td>
<td>508.6</td>
<td>443.3</td>
<td>433.5</td>
<td>474.9</td>
</tr>
<tr>
<td>Windsor</td>
<td>Windsor and Maidenhead UA</td>
<td>675.2</td>
<td>632.6</td>
<td>671.9</td>
<td>700.1</td>
<td>685.2</td>
<td>667.7</td>
<td>608.1</td>
<td>682.7</td>
<td>560.8</td>
</tr>
<tr>
<td>Worthing</td>
<td>Worthing</td>
<td>464</td>
<td>449.5</td>
<td>468.2</td>
<td>438.6</td>
<td>421.7</td>
<td>420.1</td>
<td>423.3</td>
<td>405</td>
<td>387.4</td>
</tr>
<tr>
<td>York</td>
<td>York UA</td>
<td>458.9</td>
<td>447.1</td>
<td>458.1</td>
<td>454</td>
<td>435.4</td>
<td>439.9</td>
<td>445.7</td>
<td>432.9</td>
<td>428.2</td>
</tr>
<tr>
<td>Middlesbrough</td>
<td>Middlesbrough UA</td>
<td>456.8</td>
<td>412.1</td>
<td>421.8</td>
<td>433.2</td>
<td>412.3</td>
<td>415.2</td>
<td>413.3</td>
<td>406.7</td>
<td>369.1</td>
</tr>
</tbody>
</table>
4.2 Efficiency Measurement and Regression Data

4.2.1 Efficiency Measurement Data

Table 4-3 below summarises the efficiency measurement data used in this study. There are some limitations and assumptions made in collecting this data, which are discussed further below. Firstly, firms have only been included in the data set if they have non-zero entries in the relevant regulatory returns data. This reduces the overall total number of legal entities in the study from a maximum of 171, to a maximum of 147. Secondly, the data includes all legal entities transacting UK Life business. This is inconsistent with what appears to be the most recently published UK study in this area by Hardwick et al. (2011), which has a number of exclusions as follows:

1. trust and pensions funds that offer life insurance products
2. specialized (often small local community or public sector) life and pensions providers (e.g., Police Mutual) for which complete data were either not available and/or the level of premium income written was insignificant
3. reinsurance companies that do not write direct insurance
4. subsidiaries of foreign insurers whose headquarters are not in the UK, which are said to be excluded to avoid the potentially confounding effects of transnational structures and operations on the derived measures of efficiency.

This study used all the available firm data because, while it acknowledges potential reasons for exclusions, there are also counter-arguments to those used by Hardwick et al. (2011), which would support using all the data. For example, subsidiaries of UK insurers, with headquarters in the UK, could also potentially make use of transnational structures and operations (e.g. the Aviva subsidiaries in the UK could make use of shared services with...
fellow subsidiaries within the global Aviva group\(^{56}\). In addition, even small standalone firms might make use of outsourcing facilities abroad in an effort to improve cost efficiency\(^{57}\). There could therefore be an argument on this basis to remove even more firms from the data, which is arguably counter-productive when the aim is to investigate the efficiency of as many firms as possible that are operating in this industry. A general limitation of insurance efficiency research is this emergence of UK companies making use of offshore outsourcing arrangements, thus making it difficult to measure their true inputs. All data will therefore be used, with an acknowledgement of this limitation. In addition, specialised life providers are increasingly becoming important players in the industry (e.g. Pension Insurance Corporation, which is a specialist Bulk Annuity provider\(^{58}\)), and are competing for the same business as traditional firms (e.g. Aviva is also a Bulk Annuity provider\(^{59}\), so competes directly with Pension Insurance Corporation in that market), so it seems reasonable to compare their performance. The same argument could also be applied to trust and pensions funds that offer life insurance products, because they could use any potential efficiency advantage to offer more competitive prices for similar products to those on offer from traditional firms. Finally, reinsurers are subject to many of the cost pressures of direct insurers (e.g. they are likely to need similar systems to value a set of reinsured policyholder liabilities). For this particular study, which is focussing on potential Financial and Risk Management drivers, direct insurers and reinsurers would use the tools in a similar way (e.g. reinsurers can also reinsure to other reinsurers). There is an argument to exclude reinsurers if the inputs and outputs used in the efficiency measurement are gross of


\(^{57}\) Source: https://www.insurancejournal.com/magazines/mag-features/2006/11/19/152997.htm

\(^{58}\) Source: https://www.pensioncorporation.com/

\(^{59}\) An example bulk annuity transaction by Aviva can be found here: https://www.aviva.com/newsroom/news-releases/2018/05/Aviva-wins-bulk-annuity-deal-with-ms-pension-scheme/
reinsurance, because that could potentially lead to double-counting (i.e. a block of business could appear in the data of both the direct insurer and reinsurer). However, this study is using inputs and outputs that are net of reinsurance to avoid the double-counting issue.

The inclusion of all data that was excluded by Hardwick et al. (2011) has also been performed by other recent published work (e.g. the study by Biener et al. (2016) on efficiency in the Swiss insurance industry, which appears to be the published work that is closest to this study). This study therefore utilises all available data.

A number of interesting observations can be drawn from Table 4-3. Firstly, there is a reduction in the number of firms over time, despite the outputs appearing to increase over the same period. This appears to be consistent with the industry activity discussed in section 1.1.8, which suggests that there is an industry focus on trying to obtain efficiencies via consolidation activity. Secondly, the standard deviation on Total Cost Components and Outputs are relatively large (at least double the mean in all cases). This suggests a wide variety of sizes of firms in the data set, and therefore potential for even more consolidation activity in the future. Thirdly, the data also suggests that the cost of capital is significantly higher than operating expenses in monetary terms. This is surprising at first glance, because in practice, the focus tends to be geared more towards the management of operating expenses. That said, the definition of Capital in this case is broad, as in addition to traditional debt capital such as loans, both shareholders and policyholders are also considered to be equity and debt capital owners respectively, in line with recent literature as discussed in section 3.6. The cost of capital could therefore potentially be large in monetary terms, because even a small return on assets used to back policyholder reserves can be significant in comparison to operating expenses.
### Table 4-3: Efficiency Measurement Data Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>DMU Count</th>
<th>Operating Expenses (£m)</th>
<th>Cost of Capital (£m)</th>
<th>Labour (£ per week)</th>
<th>Capital (%) p.a.</th>
<th>Net Claims (£m)</th>
<th>Invested Assets (£m)</th>
<th>Total Cost Components (£m)</th>
<th>Std Dev</th>
<th>Net Claims (£m)</th>
<th>Invested Assets (£m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>147</td>
<td>91</td>
<td>177</td>
<td>637</td>
<td>5</td>
<td>1,243</td>
<td>9,321</td>
<td>13,373</td>
<td>193</td>
<td>182,733</td>
<td>1,370,186</td>
</tr>
<tr>
<td>2008</td>
<td>147</td>
<td>91</td>
<td>173</td>
<td>699</td>
<td>4</td>
<td>1,266</td>
<td>8,027</td>
<td>13,326</td>
<td>190</td>
<td>186,141</td>
<td>1,180,040</td>
</tr>
<tr>
<td>2009</td>
<td>139</td>
<td>83</td>
<td>161</td>
<td>712</td>
<td>3</td>
<td>1,103</td>
<td>8,951</td>
<td>11,564</td>
<td>174</td>
<td>153,317</td>
<td>1,244,165</td>
</tr>
<tr>
<td>2010</td>
<td>137</td>
<td>87</td>
<td>158</td>
<td>715</td>
<td>3</td>
<td>1,149</td>
<td>9,951</td>
<td>11,900</td>
<td>182</td>
<td>157,412</td>
<td>24,817</td>
</tr>
<tr>
<td>2011</td>
<td>121</td>
<td>93</td>
<td>181</td>
<td>703</td>
<td>3</td>
<td>1,290</td>
<td>11,234</td>
<td>11,210</td>
<td>193</td>
<td>156,049</td>
<td>27,603</td>
</tr>
<tr>
<td>2012</td>
<td>114</td>
<td>104</td>
<td>178</td>
<td>686</td>
<td>3</td>
<td>1,493</td>
<td>12,454</td>
<td>11,852</td>
<td>224</td>
<td>170,166</td>
<td>30,251</td>
</tr>
<tr>
<td>2013</td>
<td>111</td>
<td>114</td>
<td>169</td>
<td>702</td>
<td>3</td>
<td>1,587</td>
<td>13,150</td>
<td>12,666</td>
<td>295</td>
<td>176,170</td>
<td>32,154</td>
</tr>
<tr>
<td>2014</td>
<td>106</td>
<td>101</td>
<td>173</td>
<td>688</td>
<td>2</td>
<td>1,492</td>
<td>14,356</td>
<td>12,690</td>
<td>209</td>
<td>158,123</td>
<td>34,382</td>
</tr>
<tr>
<td>2015</td>
<td>95</td>
<td>103</td>
<td>206</td>
<td>683</td>
<td>3</td>
<td>1,763</td>
<td>16,724</td>
<td>10,696</td>
<td>215</td>
<td>167,479</td>
<td>37,655</td>
</tr>
<tr>
<td>Total</td>
<td>1,117</td>
<td>9,773</td>
<td>19,528</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9,773</td>
<td>167,479</td>
<td>1,588,790</td>
</tr>
</tbody>
</table>

Fourthly, the mean cost of labour throughout the period suggests that the ‘average’ insurance firm is based around the Greater London area (e.g. Slough, Dorking, and Virginia Water). If a Central London office location does turn out be a significant contributor to inefficiency, then the affected firms would potentially have a plausible alternative of improving efficiency by moving the few miles from Central London to Greater London. In
addition, the large standard deviation (which is nearly half the mean in some years) suggests that there is a possibility of improving efficiency by relocating the registered office to cheaper locations from a Labour cost perspective. Fifthly, the cost of capital percentage gradually reduced over the sample period. This is consistent with the fall in interest rates over the period, given the link between interest rates and the cost of capital discussed in Section 1.1.7. It is also interesting to note that – over time – while the average cost of capital percentage went down, its standard deviation went up. This suggests that while most firms have reduced this input, there might still be some scope for other firms to improve their cost efficiency by doing the same.

Pearson correlations were used to perform some initial analysis on the data summarised by Table 4-3, and the results can be found in Table 4-4 below.

Table 4-4: Pearson Correlations of Insurance Inputs and Outputs

<table>
<thead>
<tr>
<th>Insurance Inputs</th>
<th>Insurance Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>Capital</td>
</tr>
<tr>
<td>Labour</td>
<td>100%</td>
</tr>
<tr>
<td>Capital</td>
<td></td>
</tr>
<tr>
<td>Claims</td>
<td></td>
</tr>
<tr>
<td>Invested Assets</td>
<td></td>
</tr>
</tbody>
</table>

These correlations resulted in the following observations:

- The ‘Risk-Pooling’ (claims) and ‘Financial Intermediation’ (invested assets) arms of the industry appear to go hand-in-hand (+90% correlation),
• Cost of Capital appears to be reducing over time, with the Cost of Labour going the other way, although the correlation between the two costs is weak (-20% correlation).

• There are weak positive correlations between the Cost of Labour and the level of claims, as well as the Cost of Labour and the level of invested assets. This suggests that – although the relationship is positive - increasing labour does not necessarily lead to an increase in output.

• On the other hand, there are weak negative correlations between the Cost of Capital and the level of claims, as well as the Cost of Capital and the level of invested assets. This is not surprising, since the cost of capital is reducing over time, which could potentially allow firms to raise more capital to originate new business.

The second bullet point suggests that improvement of cost efficiencies are likely to be driven by solutions that reduce labour costs. The next step in the analysis is to summarise the regression data used. This is discussed in Section 4.2.2 below.

4.2.2 Efficiency Regression Data

Table 4-5 summarises the data used in Stage 2 of the study, in conjunction with the results from Stage 1. This was reasonably clean data, with one limitation arising from the reinsurance data. Reinsurance proportions appear to be distorted by non-standard items coming into the data. For example, Equitable Life has a large negative reinsurance ratio in 2015, because of a recapture of a block of business which had been previously reinsured. This came through as a negative reinsurance premium in the data⁶⁰. Although the impact is difficult to work out in most cases, there are 93 data points that result in counterintuitive

⁶⁰ Source: http://www.equitable.co.uk/media/51360/pra-return-v1.pdf
reinsurance ratio (either less than 0, or greater than 1). Other measures of reinsurance which might avoid some of these issues appear to be more problematic from an efficiency measurement perspective. For example, a reinsurance ratio based on claims or reserves in a given year could be reflecting reinsurance arrangements entered into over multiple time periods in the past, and not just the year in question. A retrospective approach also means it is looking at how past (as opposed to current) business decisions are affecting current efficiency levels. The premium approach (and associated data limitations that come with it) is therefore still considered to be the most appropriate approach. In line with Shiu (2011), who conducted a study on Reinsurance and Capital Structure in the UK non-life insurance industry, the 93 data points discussed above are excluded from the regression analysis. In addition, five data points have also been removed from the regression analysis due to having negative premiums. This leaves a total of 1,019 data points for the regression stage of the analysis.

A number of observations were made from the data in Table 4-5. Firstly, the liquidity ratio has dropped from 30% in 2007 to 23% in 2015. This could be driven by the low interest rate environment since the Global Financial Crisis, which has probably led to firms attempting to improve competitive advantage by investing more in illiquid assets. Secondly, the use of Financial Derivatives appears to have increased in the 2008 – 2012 period (around 40%, from an average of 30%). This could be explained by firms attempting to manage market volatility during the Global Financial Crisis as well as the Sovereign Debt Crisis. Thirdly, although there was a small drop in solvency in 2008, the industry appears have had a healthy solvency position of more than 50% of free assets throughout. It however raises the question of whether capital is being utilised optimally in the industry, if such a high
proportion of it sits as free assets on the Balance Sheet. Finally, there appears to be a relatively high concentration of registered offices in Central London (around 30%), where labour costs are also the highest.

Table 4.5: Regression Data Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>DMU Count</th>
<th>LN (Premiums)</th>
<th>Reinsurance Ratio</th>
<th>Derivative Use</th>
<th>Free Asset Ratio</th>
<th>Liquidity Ratio</th>
<th>Central London Office</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>133</td>
<td>18.42</td>
<td>0.18</td>
<td>0.33</td>
<td>0.58</td>
<td>0.30</td>
<td>0.32</td>
</tr>
<tr>
<td>2008</td>
<td>129</td>
<td>18.47</td>
<td>0.18</td>
<td>0.40</td>
<td>0.52</td>
<td>0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>2009</td>
<td>126</td>
<td>18.33</td>
<td>0.18</td>
<td>0.38</td>
<td>0.55</td>
<td>0.27</td>
<td>0.33</td>
</tr>
<tr>
<td>2010</td>
<td>131</td>
<td>18.36</td>
<td>0.19</td>
<td>0.40</td>
<td>0.55</td>
<td>0.25</td>
<td>0.33</td>
</tr>
<tr>
<td>2011</td>
<td>109</td>
<td>18.19</td>
<td>0.17</td>
<td>0.37</td>
<td>0.55</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td>2012</td>
<td>104</td>
<td>18.48</td>
<td>0.16</td>
<td>0.38</td>
<td>0.56</td>
<td>0.24</td>
<td>0.29</td>
</tr>
<tr>
<td>2013</td>
<td>103</td>
<td>18.01</td>
<td>0.16</td>
<td>0.32</td>
<td>0.60</td>
<td>0.23</td>
<td>0.31</td>
</tr>
<tr>
<td>2014</td>
<td>97</td>
<td>18.09</td>
<td>0.16</td>
<td>0.34</td>
<td>0.59</td>
<td>0.22</td>
<td>0.29</td>
</tr>
<tr>
<td>2015</td>
<td>87</td>
<td>18.05</td>
<td>0.15</td>
<td>0.30</td>
<td>0.59</td>
<td>0.23</td>
<td>0.30</td>
</tr>
<tr>
<td>Total</td>
<td>1,019</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With the regression data defined, the next section discusses the validation checks done on this data, and the statistical tests used to justify the choice of the regression approach.

4.2.3 Efficiency Regression: Variable Validation

The validation of the regression variables involved performing a number of tests to check for Heteroskedasticity, multicollinearity and autocorrelation. These tests are set out in Abdoush (2017) and discussed in turn below.

1. Multicollinearity Test

The multicollinearity test aims to test the issue described by Hair et al. (2009) as the high correlation of two or more variables, which could affect the estimation of regression parameters. The test is conducted by calculating the Variance Inflation Factor (VIF), which is set out in Wooldridge (2002) as follows:
\[ VIF = \frac{1}{1 - R_i^2} \]

Where \( R_i^2 \) is the unadjusted \( R^2 \) when one variable is regressed against all the other independent variables in the model. Gujarati (2003) suggests that there is a multicollinearity problem if the mean VIF is greater than 10. Table 4-6 below shows the VIF test for the regression variables in this study, and the results suggest that there is no issue with multicollinearity.

<table>
<thead>
<tr>
<th>Variable</th>
<th>VIF (if VIF &lt; 10, there is no multicollinearity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LN (Premiums)</td>
<td>1.62</td>
</tr>
<tr>
<td>Reinsurance Ratio</td>
<td>1.05</td>
</tr>
<tr>
<td>Derivative Use</td>
<td>1.35</td>
</tr>
<tr>
<td>Free Asset Ratio</td>
<td>1.12</td>
</tr>
<tr>
<td>Liquidity Ratio</td>
<td>1.41</td>
</tr>
<tr>
<td>Central London Location</td>
<td>1.09</td>
</tr>
<tr>
<td>Mean VIF</td>
<td>1.27</td>
</tr>
</tbody>
</table>

2. **Heteroscedasticity Test**

The next test involved testing for heteroscedasticity within the data, which Johnson (1972) suggested could invalidate statistical tests of significance that assume that the modelling errors are uncorrelated and uniform, and that their variances do not vary with the effects of being modelled. The Breush-Pagan/Cook-Weisberg test can be used to test for heteroscedasticity (Breush and Pagan (1979), and Cook and Weisberg (1983)). The results of applying to the test to this study are in Table 4-7 below, and they suggest that there is no evidence of heteroscedasticity.
Table 4-7: Heteroscedasticity Test

<table>
<thead>
<tr>
<th>Breush-Pagan/Cook-Weisberg test for Heteroscedasticity (if &lt;0.05, there is heteroscedasticity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null Hypothesis: Constant Variance</td>
</tr>
</tbody>
</table>

3. Autocorrelation Test

The final test in this section tests autocorrelation (also called serial correlation) between the variables. Drukker (2003) suggests that autocorrelation in panel data can cause bias in the standard errors, resulting in less efficient results. In addition, the non-separability of variables when conducting two-stage DEA efficiency analyses has been highlighted as a limitation by a number of authors. For example, Grant et al. (2017) suggest that the assumption that the support of the inputs and outputs used to produce the DEA estimates does not depend on the independent variables used in the regression stage of the analysis is unrealistic. A test for evidence of autocorrelation in the data was therefore conducted, in order to mitigate this limitation. Results of the Wooldridge test for autocorrelation are shown below, and they suggest that there is no autocorrelation in the data.

Table 4-8: Autocorrelation Test

<table>
<thead>
<tr>
<th>Wooldridge test for autocorrelation in panel data (if &lt;0.05, there is autocorrelation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null Hypothesis: No first order autocorrelation</td>
</tr>
</tbody>
</table>

With the validation of the regression variables complete, the next step involves justifying the choice of the regression approach. This is discussed in section 4.2.4 below.
4.2.4 Efficiency Regression: Model Choice Validation

Below is a sequence of model specification tests that were performed when selecting an appropriate Regression model to use with the panel data from Stage 1 of this study, as specified by Abdoush (2017).

1. Breusch-Pagan Lagrange Multiplier (LM) Test

The LM test is used to check the model for random effects based on the simple OLS (pooled) estimator (Gujarati, 2003). If $\hat{u}_{it}$ is the $ith$ residual from the OLS regression, then the Lagrange multiplier test for one-way random effects is:

$$
LM = \frac{NT}{2(T-1)} \left( \frac{\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{u}_{it}}{\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{u}_{it}^2} - 1 \right)^2
$$

In which failure to reject the null hypothesis, i.e. the result is higher than 0.05, suggests that there are no significant differences across units and, thus, no panel effect, which means OLS regression has to be done instead. On the other hand, if the null hypothesis is rejected, the Hausman Test can then be conducted to determine whether a fixed or random effects panel regression approach is appropriate.

2. Hausman Test

The Durbin–Wu–Hausman test (also called the Hausman specification test) is a statistical hypothesis test that has to be done first in order to determine whether the panel regression belongs to the fixed effects or random effects model (Hausman, 1978). This in turn helps to capture the effects of firm and time specific heterogeneities (Gujarati, 2003). The Hausman Test is calculated as follows:
\[ H = (\beta_{RE} - \beta_{FE})' \left[ \text{Var}(\beta_{FE}) - \text{Var}(\beta_{RE}) \right]^{-1} (\beta_{RE} - \beta_{FE}) \]

Where:

- \( \beta_{FE} \) are the coefficient estimates of the time-varying covariates from the fixed effects model.
- \( \beta_{RE} \) are the corresponding estimated coefficients from the random effects model.
- \( \text{Var}(\beta_{FE}) \) and \( \text{Var}(\beta_{RE}) \) are the estimate of the asymptotic (large sample) variances and covariance of the estimated coefficients.

Therefore, if there is no correlation between the independent variable(s) and the unit effects, then estimates of \( \beta \) in the fixed effects model (\( \beta_{FE} \)) should be similar to estimates of \( \beta \) in the random effects model (\( \beta_{RE} \)) (Greene, 2008). In other words, if the result is equal or less than 0.05, the null hypothesis is rejected and the fixed effects model should be used since there is a significant difference between estimates of \( \beta \) in the two models.

3. F-Test

An F-test is any statistical test in which the test statistic has an F-distribution under the null hypothesis. It is most often used when comparing statistical models that have been fitted to a data set, in order to identify the model that best fits the population from which the data was sampled (Lomax, 2007). Suppose the fixed effects model is formulated as follows:

\[ y_{it} = X'_{it} \theta + u_i + \epsilon_{it} \]

The null hypothesis of the F-test following fixed effects regression is that in the proposed model, the observed and unobserved fixed effects \( (u_i + \epsilon_{it}) \) are equal to zero, i.e. they are equal across all units. Therefore, rejecting this hypothesis, when Prob>F is equal or less than
0.05, means that the fixed effects are non-zero, so the composite error terms \((u_i + \epsilon_{it})\) are correlated.

4. Testing for Time-Fixed Effects (Testparm)

Finally, in order to see if time fixed effects are needed when running a fixed effects model, a joint test is needed to check whether the time dummies for all years are equal to zero or not (Torres-reyna, 2007). If so, no time fixed effects are needed. On the other hand, if the Prob>F is equal or less than 0.05, the null hypothesis is rejected, meaning that coefficients for all years are not jointly equal to zero and, thus, time fixed effects have to be added to the model.

Table 4-9 below shows results of the model specification tests described above, when applied to the data in 4.2.2. These results suggest that a Random Effects approach is the most appropriate regression method to use. The Tobit approach is then chosen as the main regression model to use on the back of this, on the basis that it is a variant of the standard Random Effects approach that takes the censored outcome nature of cost efficiency scores into account.
Table 4-9: Regression Model Specification Results

<table>
<thead>
<tr>
<th>Specification Test</th>
<th>Regression Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breusch-Pagan LM test for random effects versus OLS</td>
<td>Prob&gt;chibar2 = 0.0000</td>
</tr>
<tr>
<td>[\text{if} \leq 0.05 \implies \text{use Random Effects}]</td>
<td></td>
</tr>
<tr>
<td>Hausman test for fixed versus random effects model</td>
<td>Prob&gt;chi2 = 0.1682</td>
</tr>
<tr>
<td>[\text{if} \leq 0.05 \implies \text{Fixed Effects}]</td>
<td></td>
</tr>
<tr>
<td>F-Test for fixed effects versus OLS</td>
<td>-</td>
</tr>
<tr>
<td>[\text{if } \text{Prob}&gt;F \leq 0.05 \implies \text{use Fixed Effects}]</td>
<td></td>
</tr>
<tr>
<td>Testparm (Testing for Time-Fixed Effects)</td>
<td>-</td>
</tr>
<tr>
<td>[\text{if} \leq 0.05 \implies \text{time fixed_effects needed}]</td>
<td></td>
</tr>
<tr>
<td><strong>Model Choice</strong></td>
<td><strong>Random Effects</strong></td>
</tr>
</tbody>
</table>

4.3 Efficiency Measurement Results

Table 4-10 provides a summary of the DEA results, which were produced by running the user-written STATA code described in Appendix 1. This section discusses some observations from these results. On the whole, the industry appears to be nearly fully efficient from an allocative efficiency perspective, with the allocative efficiency being close to 100% throughout, and having a small standard deviation in each year. This suggests that firms in this industry are choosing the optimal mix of input resources required to produce the necessary outputs. There is therefore very little scope to improve cost efficiency from this perspective. However, there appears to be a different picture though on technical efficiency, which starts off at 70% in 2007, before gradually decreasing to a low of 65% in 2011, and then gradually recovering after that to reach 75% in 2015. This therefore paints a picture of the technical efficiency of firms gradually reducing in the aftermath of the Global Financial Crisis, before starting to recover, and ending up with better efficiency than they
started with over the course of the post-Global Financial Crisis period. It is therefore worth understanding the technical drivers of cost efficiency or inefficiency in this period, to enable firms to understand the drivers that worked effectively (the gradual increase from 2011 suggests that there were levers that were pulled that worked well), the drivers that were not so effective, and potentially other drivers that firms had not considered, which could help or hinder efficiency. This will then be useful information to factor in when considering actions to take to improve cost efficiency.

The overall cost efficiency was relatively stable during the sample period (average: 66%, minimum: 60%, maximum: 72%). This is slightly lower than results produced by previous UK studies (e.g. 70% in Hardwick and Li (1997), and 76% in Ward (2002)). Results of the validation test using the SFA approach (which is more comparable to previous UK studies) are in Table 4-11 below, with the full STATA output in Appendix 2. The average cost efficiency on that approach was 72%, which is more in line with the results of previous studies, and suggests that cost efficiency in the industry has remained reasonably stable over time, with around 30% capacity to improve it. In terms of operating expenses, this implies that there could be potential efficiency savings (without affecting the level of output) of around £2.9bn across the industry, based on 2015 data in Table 4-3 (i.e. 30% x £9.773bn). The SFA results produced as part of this study also provide comfort that the SFA and DEA methods are not producing vastly different results. In practice, presenting potential operational expense efficiency savings on either approach (i.e. (1-66%) x £9.773bn = 3.3bn, and (1-72%) x 9.773bn = £2.7bn, based on 2015 data), or presenting them as a range (i.e. between £2.7bn and £3.3bn), is unlikely to alter the overall message of a large potential to improve cost efficiency in the industry. In the underlying results, only 33 data points from a
total of 1,117 had an efficiency score of 1. In addition, the number of fully efficient firms varies from three to five in any given year (from a total of 95 to 147, depending on the year), and only one firm is fully efficient throughout the sample period. This suggests that there is scope for a large number of firms to improve their cost efficiency.

There was an immaterial limitation that emerged as part of analysing these results, in the form of one observation with an efficiency score of 0. This was one efficiency score in the 2014 data subset where an efficiency score could not be computed, so the linear programming calculation set it to zero. Whilst this is a limitation to the results, it is a very minor one, because the results are not weighted, and it is only one observation out of 1,117, and a sensitivity of setting the zero score to 1 (i.e. the most this score could have been if it could have been computed) showed that the 2014 cost efficiency score would change from 67% to 68%, and the overall efficiency score would remain unchanged at 66%. This is therefore accepted as an immaterial limitation to the results.
Table 4-10: DEA Efficiency Scores

<table>
<thead>
<tr>
<th>Year</th>
<th>DMU Count</th>
<th>Cost Efficiency</th>
<th>Allocative Efficiency</th>
<th>Technical Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean:</td>
<td>Std Dev:</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>147</td>
<td>67%</td>
<td>21%</td>
<td>70%</td>
</tr>
<tr>
<td>2008</td>
<td>147</td>
<td>67%</td>
<td>23%</td>
<td>68%</td>
</tr>
<tr>
<td>2009</td>
<td>139</td>
<td>64%</td>
<td>22%</td>
<td>66%</td>
</tr>
<tr>
<td>2010</td>
<td>137</td>
<td>62%</td>
<td>22%</td>
<td>66%</td>
</tr>
<tr>
<td>2011</td>
<td>121</td>
<td>60%</td>
<td>21%</td>
<td>65%</td>
</tr>
<tr>
<td>2012</td>
<td>114</td>
<td>65%</td>
<td>22%</td>
<td>69%</td>
</tr>
<tr>
<td>2013</td>
<td>111</td>
<td>69%</td>
<td>23%</td>
<td>72%</td>
</tr>
<tr>
<td>2014</td>
<td>106</td>
<td>67%</td>
<td>23%</td>
<td>72%</td>
</tr>
<tr>
<td>2015</td>
<td>95</td>
<td>72%</td>
<td>22%</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>Observations 1,117</td>
<td>Mean: 66%</td>
<td>Std Dev: 22%</td>
<td>22%</td>
</tr>
</tbody>
</table>
Table 4-11: Stochastic Frontier Analysis (SFA) Results

<table>
<thead>
<tr>
<th></th>
<th>SFA Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>LN (Labour)</td>
<td>-0.3029***</td>
</tr>
<tr>
<td></td>
<td>0.0855</td>
</tr>
<tr>
<td>LN (Cost of Capital)</td>
<td>0.5287***</td>
</tr>
<tr>
<td></td>
<td>0.0348</td>
</tr>
<tr>
<td>LN (Claims)</td>
<td>-0.0203</td>
</tr>
<tr>
<td></td>
<td>0.0351</td>
</tr>
<tr>
<td>LN (Assets)</td>
<td>0.7805***</td>
</tr>
<tr>
<td></td>
<td>0.0397</td>
</tr>
<tr>
<td>Constant</td>
<td>2.1330***</td>
</tr>
<tr>
<td></td>
<td>0.6889</td>
</tr>
<tr>
<td>LN (sigma2 v)</td>
<td>-0.1778*</td>
</tr>
<tr>
<td></td>
<td>0.0937</td>
</tr>
<tr>
<td>LN (sigma2 u)</td>
<td>-0.1470</td>
</tr>
<tr>
<td></td>
<td>0.2456</td>
</tr>
<tr>
<td>sigma_v</td>
<td>0.9149</td>
</tr>
<tr>
<td></td>
<td>0.0429</td>
</tr>
<tr>
<td>sigma_u</td>
<td>0.9292</td>
</tr>
<tr>
<td></td>
<td>0.1141</td>
</tr>
<tr>
<td>sigma2</td>
<td>1.7005</td>
</tr>
<tr>
<td></td>
<td>0.1567</td>
</tr>
<tr>
<td>Lambda</td>
<td>1.0155</td>
</tr>
<tr>
<td></td>
<td>0.1506</td>
</tr>
<tr>
<td>Observations</td>
<td>1,117</td>
</tr>
</tbody>
</table>

*** 1% significance level, ** 5% significance level, *10% significance level, all using a one-sided t-distribution test

<table>
<thead>
<tr>
<th></th>
<th>72%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Efficiency</td>
<td></td>
</tr>
<tr>
<td>Std Dev</td>
<td>13%</td>
</tr>
</tbody>
</table>

The next step of the analysis is to discuss observations from the regression results that used the efficiency scores from this section as dependent variables. These regression results are discussed in section 4.4 below.
4.4 Efficiency Regression Results

Table 4-12 below provides regression coefficients of each independent variable, with the error term below each coefficient. It also shows the statistical significance of each variable in the regression. Details of the user-written STATA code for the Simar and Wilson (2007) bootstrapping technique and the STATA outputs for the regression analysis can be found in Appendices 3 and 4 respectively. The observations from these results are discussed below.

Table 4-12: Efficiency Regression Results

<table>
<thead>
<tr>
<th></th>
<th>Validation Model: Random Effects</th>
<th>Validation Model: OLS</th>
<th>Validation Model: Simar and Wilson</th>
</tr>
</thead>
<tbody>
<tr>
<td>LN (Premiums)</td>
<td>0.0024</td>
<td>0.0075***</td>
<td>-0.0003</td>
</tr>
<tr>
<td></td>
<td>0.0020</td>
<td>0.016</td>
<td>0.0014</td>
</tr>
<tr>
<td>Reinsurance Ratio</td>
<td>-0.0345**</td>
<td>-0.075***</td>
<td>-0.0587***</td>
</tr>
<tr>
<td></td>
<td>-0.0148</td>
<td>0.0147</td>
<td>0.0124</td>
</tr>
<tr>
<td>Derivative Use</td>
<td>-0.0105</td>
<td>-0.0308***</td>
<td>-0.0149**</td>
</tr>
<tr>
<td></td>
<td>0.0083</td>
<td>0.0084</td>
<td>0.0073</td>
</tr>
<tr>
<td>Free Asset Ratio</td>
<td>0.0100</td>
<td>0.0243</td>
<td>0.0050</td>
</tr>
<tr>
<td></td>
<td>0.0148</td>
<td>0.0162</td>
<td>0.0137</td>
</tr>
<tr>
<td>Liquidity Ratio</td>
<td>-0.0064</td>
<td>0.0193</td>
<td>0.0064</td>
</tr>
<tr>
<td></td>
<td>0.0175</td>
<td>0.0159</td>
<td>0.0139</td>
</tr>
<tr>
<td>Central London Office</td>
<td>-0.4052***</td>
<td>-0.4201***</td>
<td>-0.4251***</td>
</tr>
<tr>
<td></td>
<td>-0.4063***</td>
<td>-0.4251***</td>
<td>-0.4251***</td>
</tr>
<tr>
<td></td>
<td>0.0138</td>
<td>0.0078</td>
<td>0.0068</td>
</tr>
<tr>
<td>Total Observations</td>
<td>1,019</td>
<td>1,019</td>
<td>1,019</td>
</tr>
<tr>
<td>• Left-censored</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Right-censored</td>
<td>32</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Uncensored</td>
<td>986</td>
<td>1,019</td>
<td>986</td>
</tr>
<tr>
<td>R-squared</td>
<td>-</td>
<td>0.7514</td>
<td>0.7576</td>
</tr>
</tbody>
</table>

*** 1% significance level, ** 5% significance level, * 10% significance level, all using a one-sided t-distribution test

One observation was left-censored, having an efficiency score of zero. This observation was discussed in Section 4.3 as a minor limitation, having been set to zero because the score could not be computed. The same conclusion of this being an immaterial limitation also applies to the regression analysis. At the other end, only 32 data points from a total of 1,019
were right-censored as a result of having an efficiency score of 1. This is one lower than the 33 discussed in 4.3, due to one data point being removed as part of the data clean-up process for the regression analysis.

Three of the six hypotheses tested returned statistically significant results, thus supporting the thesis that Financial and Risk Management, Firm Size and Office Location are drivers of either cost efficiency or cost inefficiency of firms in the UK Life Insurance industry in the period after the Global Financial Crisis. Each hypothesis is discussed in turn below.

The firm size finding is significant at the 10% level, and supports the hypothesis that larger firms are more cost-efficient than smaller firms. The consolidation activity discussed in section 1.1.8 might have therefore contributed to the recovery in the industry-wide efficiency since 2011. In addition, the analysis in 4.2.1 suggests that there is scope for more consolidation activity, and since section 1.1.8 suggests that consolidation remains the focus of the industry going forward, further efficiency gains might also emerge in future as a result. This finding is consistent with the corresponding finding for this industry in Hardwick and Li (1997)'s study in terms of the positive contribution to cost efficiency, but is inconsistent in terms of statistical significance, because the finding was statistically insignificant in the previous finding. This provides an example of how findings can change over time and the need to reassess efficiency and inefficiency drivers when new information emerges.

The reinsurance finding is also significant at the 10% level, but the impact is not what was expected, with the findings rejecting the hypothesis that reinsurance increases the cost
efficiency of a UK insurance company. This finding is initially surprising, given the discussion in section 3.8. However, the European Regulatory Capital regime pre-January 2016 did not give credit for reinsurance in Regulatory Capital Requirements\textsuperscript{61} (so only the cost of reinsurance came through, with the benefit of reduced risk/volatility not quantified or reflected on the Balance Sheet). The Solvency II regime from January 2016 does give credit to reinsurance in the Regulatory Capital calculation\textsuperscript{62}, so a future study (when enough years have passed to create sufficient data) could consider whether reinsurance remains a negative influence on cost efficiency.

Although the Derivative Use finding is not statistically significant, the coefficient also goes against what was expected, although unlike reinsurance, it was difficult to determine what to expect, given the apparent lack of relevant literature on this subject (as discussed in section 3.8). The treatment of derivatives in the regulatory capital calculation is consistent with reinsurance before and after January 2016, so it is unsurprising that the findings are also consistent. A future study proposed for reinsurance should therefore also consider derivatives under the Solvency II regime.

The free asset finding suggests that there is insufficient evidence to support the hypothesis that free assets hinder cost efficiency. Brockett et al. (2004) came to a similar conclusion in a study based on U.S. data. That said, the positive sign of the coefficient raises the question of whether it is cheaper to raise capital (and hold it on the Balance Sheet as a volatility buffer) than pay for Reinsurance or Derivatives. Put another way, it would appear better from an efficiency perspective to use the solvency volatility buffer approach (since free assets do not

\textsuperscript{61} Source: https://www.handbook.fca.org.uk/handbook/INSPRU/1/1.html?date=2009-12-14
\textsuperscript{62} Source: https://www.pwc.com/il/en/insurance/assets/qis5frank1.pdf
significantly affect cost efficiency one way or the other) than use derivatives or reinsurance (which negatively impact cost efficiency).

There is also insufficient evidence from the results to support the hypothesis that higher liquidity leads to higher cost efficiency. This suggests that the reduction in liquid assets over the sample period (and the corresponding increase in illiquid assets) is not having an impact on cost efficiency. This is an important finding, since – in practice – illiquid assets would be expected to be more labour-intensive to manage than liquid assets (e.g. specialist staff required to agree the terms of an illiquid asset such as an Equity Release Mortgage discussed in section 1.1.5). It is therefore important to find that any additional cost inefficiencies from increasing illiquid asset holdings are statistically insignificant.

Finally, the results support the hypothesis that a Central London registered office location decreases cost efficiency at the 1% level. This finding is consistent with Central London having the highest wages (a key insurance input). Hardwick and Li (1997) found a similar finding, but it was not statistically significant at the time. Reasons why the finding is now significant might include the different approaches of looking at the Cost of Labour, since the earnings data in the Hardwick and Li (1997) study did not vary by location, whereas this data varies by local authority in this study. Changes to the economy in general, which now make it more cost-effective to operate from outside Central London than it might have done over 20 years ago (e.g. Broadband in more UK locations63), might also be a factor. The affected companies may wish to consider moving their registered offices outside Central London. Technological advances (such as Broadband in more UK locations) and new working

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63 Current UK Broadband coverage is around 95%. Source: https://www.gov.uk/guidance/broadband-delivery-uk
patterns (e.g. working more from home\textsuperscript{64}) arguably support a more geographically diverse workforce.

Table 4-12 also shows the validation results, which show the regression results using the Random Effects, OLS and Simar and Wilson approaches. The coefficients of the independent variables across all the models appear to be of a similar size, with the main variations coming from the statistical significance of these coefficients. That said, all four models are consistent in suggesting that Reinsurance and a Central London office location have a statistically significant negative relationship with cost efficiency, and that the relationships between cost efficiency and the Free Asset and Liquidity Ratios are statistically insignificant. In addition, Derivatives Use has a negative sign in all models, and is statistically significant at the 1\% and 5\% significance level in two of the four models. Practitioner audiences could arguably put more weight on these findings, because they appear to withstand the debate in the academic literature about the most appropriate regression approach to use.

This chapter has so far analysed specific aspects of the findings of this study, and attempted to link them to findings from existing literature where relevant. The next section attempts to have a broader discussion about the findings.

\section*{4.5 Discussion}

\subsection*{4.5.1 Findings}
By using the DEA approach to efficiency measurement, this study appears to be the first one in the UK to explore the key components of cost efficiency separately (i.e. technical and allocative efficiency). It therefore appears to be the first study to report that the UK Life Insurance industry appears to have near-perfect allocative efficiency. Although it is difficult

\textsuperscript{64} The increasing trend of remote working in the UK is discussed here: https://www.hso.co.uk/leased-lines/technology-news/homeworking-news/50-of-uk-workforce-to-work-remotely-by-2020
to make comparisons with other industries, which use different data sets and different sample periods, it is still worth noting how this level of allocative efficiency compares to other key important markets, where the comparative information is available. In this regard, the picture appears to vary across Europe, with some markets appearing to have similar near-perfect allocative efficiency, while others have efficiency scores that are much lower in comparison. For example, the Swiss Life Insurance Industry had near-100% efficiency, based on Biener et al. (2016). On the other hand, other markets appear to have more modest allocative efficiency. An example can be seen in the German Life insurance market, where allocative efficiency averaged 51%, based on Diboky (2007). From a global perspective, a study of the U.S. Life insurance industry by Cummins et al. (2010) found allocative efficiency in the Life and Health market to be around 62%. Given that the German insurance market is a key competitor to the UK market in Europe, and that the U.S. is the leading insurance market globally and a key global competitor (as discussed in section 1.1.1), the UK insurance industry can arguably be considered to be a global leader on this measure of efficiency, and one that other industries could learn from in order to improve their allocative efficiency.

Although the UK Life Insurance market appears to be highly allocative efficient, there appears to be capacity to improve overall cost efficiency. The findings of this study suggest that cost efficiency using up to date data is not too dissimilar to the cost efficiency found in similar studies for this industry. This suggests that the industry is capable of adjusting to the changing economic environment to maintain a level of efficiency (e.g. the consolidation activity after the Global Financial Crisis, as discussed in section 1.1.8). However, the absence of a significant improvement in cost efficiency since those earlier studies, suggests that the industry is reactive (as opposed to proactive) to changes in the economic environment. This
might be due to what the industry perceives is required to significantly improve efficiency, which is usually associated with significant change-related projects. For example, all previous studies on this industry focus on organisational form (e.g. shareholder firm versus mutual, as covered by Hardwick et al. (1997)) or Distribution Systems (as covered by Ward (2002)). In addition, current industry activity discussed in section 1.1.8 suggests that the industry is looking to Consolidation as a potential source of efficiency. All these activities would – in practice - require very significant business decisions and changes. Practitioners are therefore unlikely to implement them unless they absolutely need to. However, there might be smaller changes available that do not require fundamental changes to a firm’s business to significantly improve cost efficiency, as this study has found. For example, reviewing reinsurance arrangements can be a management action, which does not normally require fundamental changes to the business. Having a toolkit of these easy-to-implement efficiency drivers might encourage firms to be more proactive from a cost efficiency perspective, as well as more agile in times of crisis. For example, the trend of cost efficiency scores suggest that cost efficiency was on a downward trend after the Global Financial Crisis until 2011, when it finally started to recover. A toolkit that is easier to implement might have improved the industry’s efficiency earlier than this point. This study has shown that the category of Financial and Risk Management offers such tools, and further research could explore the impact of other initiatives that could be implemented without major business changes, such as Human Resource and Process Management or Product Pricing, which have been explored in other markets as discussed in section 2.3.2.

Future studies could also explore whether easily available industry data such as a market index could be used to predict the trend of cost efficiency. An example of this can be seen in
Figure 4-1, which shows the FTSE100 index falling sharply in the aftermath of the Global Financial Crisis, before starting to recover, in a similar way to how cost efficiency itself has progressed since the crisis, as plotted in Figure 4-2.

Figure 4-1: FTSE 100 Index from Year-end 2007 to Year-end 2015

![FTSE 100 Index Chart](image)

Source: S&P Market Intelligence

Figure 4-2: Cost Efficiency in the UK Life Insurance Industry

![Cost Efficiency Chart](image)

DEA Efficiency Scores (Optimal Efficiency = 100%)

- Average = 66%
A Pearson correlation of the underlying data of these graphs can be seen in Table 4-13 below, which suggests a strong association between them. This raises the question of whether a combination of efficiency scores from a published academic piece of work, and a widely published market index, such as the FTSE 100, could be used to derive an easy and real-time approximation of overall cost efficiency in the industry.

Table 4-13: Cost Efficiency and the FTSE 100 Correlation

<table>
<thead>
<tr>
<th>Cost Efficiency</th>
<th>FTSE 100 Index</th>
<th>FTSE Index Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007 67%</td>
<td>6425.38</td>
<td>31-Dec-07</td>
</tr>
<tr>
<td>2008 67%</td>
<td>4427.00</td>
<td>29-Dec-08</td>
</tr>
<tr>
<td>2009 64%</td>
<td>5416.12</td>
<td>28-Dec-09</td>
</tr>
<tr>
<td>2010 62%</td>
<td>5955.77</td>
<td>27-Dec-10</td>
</tr>
<tr>
<td>2011 60%</td>
<td>5548.82</td>
<td>26-Dec-11</td>
</tr>
<tr>
<td>2012 65%</td>
<td>6015.59</td>
<td>31-Dec-12</td>
</tr>
<tr>
<td>2013 69%</td>
<td>6732.24</td>
<td>30-Dec-13</td>
</tr>
<tr>
<td>2014 67%</td>
<td>6573.60</td>
<td>29-Dec-14</td>
</tr>
<tr>
<td>2015 72%</td>
<td>6276.98</td>
<td>28-Dec-15</td>
</tr>
</tbody>
</table>

Correlation 40%

Although this study attempted to explore statistically robust efficiency drivers, cost efficiency could also arguably be driven by a firm’s inputs not being as volatile as its outputs, and particularly the value of invested assets. For example, assuming no asset defaults and no increase to the cost of capital, the same number of assets will need to be managed, even if the value of those assets has decreased. A similar number of staff will therefore be required, so a reduction in efficiency appears to be unavoidable for some firms because the wage data in section 4.2.1 has shown that – even during the crisis – salaries remained relatively stable. This is therefore likely to create an opportunity for some firms to outperform a potential phenomenon that affects the rest of the market, and reducing the overall efficiency of the industry as a result.
Although firm-based results have not been published in this study, practitioners could make use of the methods and data in this study to conduct similar analysis on efficiency measurement, to deduce how they compare with peers. This could help firms understand which competitor firms they need to learn from to improve their efficiency, or indeed how much effort to put on finding efficiencies, if a firm is already operating on the efficient frontier. For example, one firm appears to be the only one to have had 100% cost efficiency throughout the sample period. It would be useful for the firm’s owners, board members and management to be aware of this, to aid with (say) setting expectations for the performance of senior managers with regards to finding additional efficiency savings. If the firm is already holding a market-leading position on this front, it might be more difficult to extract additional efficiency savings from it, so managers tasked with finding these additional savings, could potentially be set up to fail.

4.5.2 Comparison with other studies
This study is consistent with previous UK studies in that it focusses on the Life segment of the market, and appears to use similar inputs and outputs that were used in most of the papers. However it appears to deviate from these previous studies in three key areas:

1. It updates the data by using post-Global Financial Crisis period (none of the previous studies appear to do that), so new insights are gleaned, even where a determinant has been explored before, because much could have changed in the intervening period.

2. It aligns the methodology to the latest methods being used globally, and away from traditional methods of calculating efficiency or performing regression analyses.
3. All previous studies appear to have explored either the categories of Organisational Form and Corporate Governance, or Distribution Systems. This study deviates away from that by looking at Financial and Risk Management.

In terms of other published papers that focus on Financial and Risk Management (FRM), this study appears to be unique. While there are some key cross-overs (e.g. 6 of the 8 Financial and Risk Management papers also look at the determinants of Cost Efficiency), this study appears to be the first to explore reinsurance, derivative use and liquidity as potential drivers of (in) efficiency. It also appears to be the first study that explores the FRM determinants of a single European country (the one other European study that looks at FRM, by Eling and Jia (2018), is a Europe-wide study that incorporates 16 countries).

The published work that appears to be closest to this study was arguably produced by Biener et al. (2016), which looked at the determinants of efficiency and productivity in the Swiss insurance industry. There are a number of similarities between that study and this one. For example, a two-stage efficiency analysis on the insurance industry of a single Western European country was conducted, using the non-parametric DEA approach in the first stage, supplemented by the latest Simar and Wilson truncated bootstrapping regression technique (which was used for validation purposes in this study). The core data was also obtained from regulatory returns, and covers the whole industry, and the efficiency scores are calculated using similar inputs and outputs to this study, which use a value-added approach to outputs. In addition, the second stage also explores one of the more recent categories of research in the area of efficiency in the insurance industry (Product Pricing and Target Markets). Finally, the data set contains up to date data that captures part of the post Global Financial Crisis period (their study uses a 1997 – 2013 sample period).
While there appear to be a number of similarities between this study and the one by Biener et al. (2016), there are also key differences. For example, Biener et al. (2016) focus on a different European Market, where the regulations are similar, but not perfectly aligned (Switzerland sits outside the EU, and has its own insurance regulatory regime, which is enforced by the Swiss Financial Market Supervisory Authority\(^{65}\)). This could affect the significance of some of the determinants. In addition, the data in the Swiss study covers both Life and Non-life insurance, whereas the focus in this study is on life insurance. That could affect both the level of efficiency (a previous Europe-wide study by Fenn et al. (2008) found that the UK non-life insurance industry was one of the most efficient in Europe, while the life insurance industry was one of the least efficient) as well as the significance of determinants. The study by Biener et al. (2016) also assigns an industry-wide wage variable to all firms, whereas this study attempts to be more precise by assigning wages to firms according the local authority where each registered office is found. This was important to do in this study, since there appears to be a large disparity between regions (and specifically between Central London and the rest of the country), so this could have a bearing on the significance of the Office Location finding. The Swiss study also bases its results on a much longer sampling period than in this study (1997 – 2013). This suggests that a longer sample period could have also been used in this study if it was considered valuable to do so. However, the focus in this study is on the post Global Financial Crisis period, and the chosen length of the sample is considered appropriate, based on the discussion in section 3.10. Biener et al. (2016) extend their study to measuring productivity over time using the Malmquist index of Total Factor Productivity. This is not covered in this study, as the focus

\(^{65}\) Source: https://www.finma.ch/en/supervision/insurers-cross-sectoral-tools/swiss-solvency-test-sst/
for the UK insurance market practitioners (of which the researcher is a part) appears to be on improving operational (i.e. cost) efficiency as discussed in section 1.1.8, so this research (and many others in the literature that has been reviewed) can stand on its own by focusing on the measurement of the efficiency, and the potential drivers that significantly help or hinder it. Finally, in addition to Cost Efficiency, their study also measures and considers the determinants of Revenue Efficiency. This has also not been explored in this study (along with Profit Efficiency) because the current focus of the industry appears to be on operational efficiency, as discussed in the bullet point above. Further studies can explore these additional topics when the industry’s focus shifts from operational efficiencies to other types of efficiency.

4.5.3 Strengths and Limitations
The analysis conducted under this research features both strengths and limitations. The first contribution of the study is the breadth of industry coverage. The data covers the whole UK Life Insurance Industry, thus removing any sampling error from that perspective. It also implies that the findings are widely generalizable in this industry. An additional strength of this study is the use of the latest and widely accepted methodology in the research area. This will hopefully make the findings more acceptable to fellow researchers in the area. This study also brings an industry practitioner perspective to this research area, which appears to be dominated by academic researchers. Chapter 1 of this paper, the choice of research questions and the justification of methodological choices are likely to reflect this practitioner perspective.

In terms of limitations, the first one is a general one for this type of research. As with any purely empirical study, it answers the ‘what’ question, not the ‘why’, which practitioners
and fellow researchers would arguably also have an interest in, and is often addressed very briefly as part of the results analysis and discussion. The ‘why’ element is proposed as a topic of future research. In addition, this study is a snapshot in a continuously moving economic and regulatory landscape (e.g. the solvency regime in Europe was completely revamped as at 1 January 2016, and part of the effect was to change the way Reinsurance and Derivatives were viewed from a Required Capital perspective). The findings are therefore only likely to be relevant to a short period, and would need to be updated once enough new data emerges (maybe around 2025, when there will be a similar volume of data post-2016 to the pre-2016 data in this study). Finally, although section 4.2.4 justifies the regression approach chosen, this study may still be considered to have a methodological weakness due to the issue of non-separability of between the first stage and second stage of the analysis, as discussed by Grant et al. (2017). Having discussed various aspects of the results in this section, the next and final chapter builds on this, by providing conclusions to this study.
Chapter 5: Conclusions
5 Conclusions

This chapter starts by recapping on the purpose of this study, as well as the research questions. The purpose of this study is to conduct an empirical investigation on the level of cost efficiency in the UK Life Insurance industry during and after the Global Financial Crisis, as well as test the statistical significance of a sample of potential drivers of efficiency that are largely drawn from the area of Financial and Risk Management. This purpose has helped to shape the two key research questions in this study. The first question asks about the level of cost efficiency in the industry at the end of each year, from 2007 to 2015, and what the average level was over the whole period. The second question looks to explore the statistical significance of reinsurance cover, financial derivative use, free assets on the Balance Sheet, the level of liquid assets, the size of a company and a Central London office location on insurance firms’ cost efficiency inefficiency. The rest of this section summarises the findings of this research, the implications this research has on theory and practice, and suggestions for future research.

5.1 Research Key Findings

5.1.1 Chapter 1 Summary

Chapter 1 provides the context of the UK insurance industry, and highlights its significance both as a leading European and leading global insurance industry. It then goes on to discuss recent developments in the industry, which highlight why – even though previous studies have been conducted - another look at cost efficiency in this industry might be appropriate at this time. The chapter suggests that, in a challenging economic environment, one aspect that firms are pursuing to keep their businesses profitable appears to be the improvement of cost efficiency. A survey of industry practitioners by one of the ‘Big 4’ Financial Advisory firms – PwC - highlights that the industry focus is on consolidation, with the objective to “integrate functions and improve efficiency through outsourcing and generate shareholder
and policyholder value through generating expense and tax efficiencies. It is therefore important for the industry to understand whether there is actually any capacity to improve efficiency, and consider if some of the tools being employed will help firms to meet their objective.

5.1.2 Chapter 2 Summary
Chapter 2 starts by providing a theoretical framework for conducting empirical efficiency research on the UK Insurance Industry. This framework starts by identifying the UK economy as liberal, in line with Hall and Soskice (2001), and justifies why the Efficient Structure Hypothesis, which was developed by Demsetz (1973), is an appropriate underpinning theory of performance for the chosen industry, when other theories can be applied. The chapter then reports the details of the relevant global published and peer-reviewed empirical literature review, which is presented in two grids – one that looks at Efficiency Measurement, while the other looks at Efficiency/Inefficiency drivers. The efficiency measurement review highlights the different types of efficiency and efficiency measurement techniques that exist, including the debate in the literature about the appropriate techniques to use, as well as the appropriate method of choosing insurance inputs and outputs. Consequently, this study identifies the following gaps in the literature; firstly, no published paper focusing on the UK Life Insurance Industry since 2011; secondly, no UK Life Insurance industry study that covers the post-Global Financial Crisis period, when a number of economic and regulatory changes occurred that might affect cost efficiency; and finally, no UK study has used the popular Data Envelopment Analysis (DEA) method of efficiency measurement. There also appears to be scope to increase non-U.S. literature, because nearly 30% of literature reviewed was based on U.S. insurance industry data.

The review of Efficiency/Inefficiency drivers in the literature found a variety of regression approaches used, with efficiency scores as the dependent variable in the regression analysis. A number of regression methods could therefore be used, with justification. In terms of efficiency drivers, the findings from the papers are grouped into the following categories (in order of popularity in the empirical literature), which were introduced by Eling and Luhnen (2010), unless stated otherwise:

1. Organisational Form and Corporate Governance
2. General level of efficiency, and evolution over time
3. Methodology and Assumptions
4. Scale and Scope Economies
5. Regulation Change
6. Market Structure
7. Financial and Risk Management
8. Distribution Systems
9. Product Pricing and Target Markets (created in this study)
10. Mergers and Acquisitions
11. Intercountry Comparisons
12. Human Resources and Process Management (created in this study)

The findings in each of these categories are consistent across different studies in some cases, but also conflicted in others. This arguably suggests that – even though quantitative research methods were used by all previous studies, efficiency research is not an exact science, given the considerable debate on various aspects of the methodology. The contrasting findings within the same geographical area also suggest that the findings are
only generalizable for firms within the industry in question, and not necessarily outside it. And even then, the generalisability might only apply for a certain time period, because regulatory changes might affect some of the actions taken by firms, and therefore the data that feeds into the analysis. The analysis also highlights that there does not appear to be a UK study that has looked outside of Organisation Form and Corporate Governance or Distribution Systems for potential efficiency/inefficiency drivers. In addition, Financial and Risk Management appears to have only been explored by a handful of studies, and only one, by Eling and Jia (2018) appears to focus on Europe, and even that includes data from 16 countries (including the UK), so is not focussed on a specific country. The rest of the chapter explores the European segment of the literature in more detail, by critically analysing the findings, and helps to support the research purpose and questions of this study.

5.1.3 Chapter 3 Summary
Chapter 3 sets out the methodology that is used in this research. The key methodology decisions that have been made are as follows:

**Data Sources:** The financial information of insurance companies could either be obtained from accounting information, or regulatory returns. This study has opted for regulatory returns, because of the unavailability of accounting data for unlisted or mutual insurers. The next decision relates to the source of the regulatory returns. There appear to be a couple of credit rating agencies that collate UK insurance regulatory returns, namely Standard and Poor’s (S&P) and A.M Best. S&P (and specifically, their SynThesys Life Database, version 10.1) has been chosen because the researcher could easily get access to their data as part of their employment at Canada Life, but the A.M Best data would have worked too. As a
validation check, a regulatory return from an insurer’s website\textsuperscript{67} has been downloaded and cross-checked against what was stored for this company by S&P, and this validation test has passed.

**Sample Period:** Because the focus of this study is on the Global Financial Crisis and beyond, the data period starts off at 2007 (the start of the Global Financial Crisis, as discussed in section 3.10). The end-point of the period of the study has been chosen to capture the longest period since the crisis, given the data available at the point of data collection. As at March 2018 (when data was collected), The SynThesys Database had regulatory returns data up to 2015. This would provide 9 years of industry data, which is slightly shorter than the 11 years in Hardwick et al. (2011)’s UK study, but longer than the periods used by all the other UK-focussed published studies discussed in section 2 (5 years in Hardwick and Li (1997), Letza et. al (2001) and Klumpes (2004), and 8 years in Ward (2002)).

**Choice of Insurance Outputs:** There appears to be considerable debate in the literature about the choice of insurance outputs. Claims and Invested Assets have been chosen as the outputs, by looking at an insurance company as a value-adding entity, with Claims representing the Risk-Pooling service offered by an insurance company, while Invested Assets represents the Financial Intermediation service. These choices have been influenced by a combination of what has been previously used in the literature (especially in the UK and the U.S.A) and the researcher’s understanding (as a practitioner) of the purpose and function of an insurance company. There appears to be less debate about Insurance inputs

\textsuperscript{67} The 2009 submission by Wesleyan Assurance Society: https://www.wesleyan.co.uk/pdf/wesleyan_assurance_society_fsa_returns_2009.pdf
in the literature, and the chosen inputs of Labour and Financial Capital appear to be widely accepted.

**Efficiency Measurement Methodology:** There is discussion in the literature about whether to use parametric (e.g. Stochastic Frontier Analysis or SFA) or non-parametric (e.g. DEA) approaches to measuring efficiency. The main limitation with the parametric approach appears to be the number of key assumptions that are required in the cost or production function (e.g. the distribution of the error term), while the main limitation of the non-parametric approach is the loss of the statistical qualities that you get with a parametric approach. While the overall efficiency scores have been calculated using both the SFA and DEA approaches in this study, the DEA results form the basis of this research for a number of reasons. Firstly, the DEA approach can be used to decompose Cost Efficiency into its various components (i.e. technical and allocative efficiency). This appears to be the first UK study to do this, and will help practitioners to understand the cost-saving capacity at a more granular level. Secondly, DEA also appears to be more suited to answering the research question on the development of efficiency over time. Thirdly, although most of the previous UK studies appear to be silent on the statistical significance of the error term, one study - by Ward (2002) - assumes that the random error term tends to zero over the period covered by the analysis. This supports the use of the DEA approach in future UK studies (or at least suggests that it is as valid as econometric approaches in the UK context), which does not separate the random error term from the inefficiency term. Finally, choosing this approach will make this UK study consistent with most recent efficiency studies conducted in other countries on this key methodological aspect.
**Regression Methodology:** Although a variety of regression approaches appear to be acceptable in the literature, there is some discussion in the literature about the regression approach if the censored (0, 1) nature of efficiency scores is taken into consideration. Some papers appear to use a Tobit approach, while others use the truncated bootstrap approach introduced by Simar and Wilson (2007). This study uses both approaches, but bases the findings on the Tobit approach. The shortcomings of the Tobit approach are acknowledged (principally the use of conventional approaches to inference, which are invalid due to complicated and unknown serial correlations among estimated efficiency scores), but section 4.2.4 provides statistical justification for why it is the appropriate method to use in this study. A Random Effects approach and a simple OLS approach are also used alongside the Simar and Wilson approach for validation purposes.

In terms of ethics considerations, the study is based on publicly available secondary data, and therefore does not need ethics approval from the University of Hertfordshire. That said, there is an acknowledgment in the chapter about general ethical considerations that are considered, even if formal approval is not required.

**5.1.4 Chapter 4 Summary**
Chapter 4 starts with analysing the data that has been collected for the purpose of this study. The core data set was downloaded from the SynThesys Life Database (version 10.1), as discussed in 5.1.3 above. In addition, the study uses earnings population from the Office of National Statistics as the cost of labour, with data manually collected from Companies House, the Mutuuals Public Register and the Financial Services Register being used to assign earnings (which are by local authority) to a firm. The data shows a wide variety of firm sizes and registered office locations (although there appears to be a high concentration of
registered offices with a Central London address). The data also provides useful insights in the level and/or use of common Financial Risk Management tools.

From the DEA analysis, the findings suggest that the average cost efficiency in this period is 66%. It starts out at 67% in 2007, before gradually decreasing to a low of 60% in 2011, and then recovering to reach 72% in 2015. In the second stage, a Central London office location and Reinsurance Cover are found to have a negative and statistically significant relationship with cost efficiency, while Firm Size has a statistically significant positive relationship. The office location finding is consistent with wages (which appear to be highest in Central London) being a key input for an insurance company, while the reinsurance finding suggests that the cost of reinsurance outweighs the quantifiable benefits. The Firm Size finding suggests that larger firms are more cost-efficient than smaller firms. Finally, the findings suggest that Solvency and Liquidity do not significantly contribute to (in) efficiency.

The most interesting finding related to reinsurance, because it is unexpected, based on the literature review that has been conducted. However, the UK Regulatory Capital regime pre January 2016 did not give credit for reinsurance in Regulatory Capital Requirements (So only cost came through the financial statements, with the benefit of reduced risk/volatility not quantified). The regime after January 2016 (known as Solvency II) does give credit to reinsurance (and derivatives) in the Regulatory Capital calculation, so a future study (when enough years have passed to create sufficient data) could consider reinsurance and derivatives again. If this switches from negative to positive significance, it will highlight the role of regulators in influencing cost efficiency.
The overall cost efficiency over the sample period of 66% is slightly lower than results produced by previous UK studies (e.g. 70% in Hardwick and Li (1997), and 76% in Ward (2002)). The validation test using the SFA (which was also used in previous studies) produced an average efficiency of 72%, which is more consistent with previous studies, and suggests the slight difference between the results of this study and those of previous studies might be partly due to methodological differences. There are research papers dedicated to exploring the significance of differences between the two approaches, and the findings appear to be inconclusive (some see statistically significant differences, while others do not).

Hardwick and Li (1997) found a similar finding for Office Location, but it was not statistically significant at the time. Reasons why the finding is now significant might include different approaches of looking at the Cost of Labour, since the earnings data in the Hardwick and Li (1997) study did not vary by Office Location, and changes to the economy in general, which now make it more cost-effective to operate from outside Central London than it might have done over 20 years ago (e.g. Broadband in more UK locations\(^68\)). The affected companies may wish to consider moving their registered offices outside Central London. Technological advances (such as Broadband in more UK locations) and new working patterns (e.g. working more from home\(^69\)) arguably support a more geographically diverse workforce. Hardwick and Li (1997) also found a similar finding for Firm Size, but it was again not statistically significant at the time. This might also be explained by technological advances (e.g. computing power) might mean companies might now be able to use similar computer

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\(^68\) Current UK Broadband coverage is around 95%. Source: https://www.gov.uk/guidance/broadband-delivery-uk

\(^69\) The increasing trend of remote working in the UK is discussed here: https://www.hso.co.uk/leased-lines/technology-news/homeworking-news/50-of-uk-workforce-to-work-remotely-by-2020
hardware regardless of the volume of data being processed. This could therefore lead to
larger firms being more efficient). The solvency finding is not statistically significant and is
consistent with similar findings from previous literature in this regard (e.g. Brockett et al.
(2004)).

Reinsurance, Liquidity and Derivative Use do not appear to have been previously explored
as determinants of cost efficiency in the insurance industry literature. This study therefore
appears to make a novel contribution to this body of literature. In addition, the chapter also
includes a correlation of 40% between cost efficiency scores and the FTSE 100 index, thus
raising the question of whether cost efficiency since the most recent published results in
academic literature can be approximated by a combination of the published result and the
(pure or adjusted) movement of a published index since that result. This is proposed as a
subject of future research.

5.2 Implications for Theory
This study appears to be the first in the UK Life insurance industry to consider cost efficiency
during and after the Global Financial Crisis, as well as the first UK study to focus on potential
FRM (in) efficiency drivers. It also adds to the body of empirical literature in this area in the
UK (there appear to only be 5 pieces of published work that focus on the UK), and also adds
to a relative new sub-area of research in Financial and Risk Management (there appear only
be eight previously published studies globally, and only one of those appears to be focussed
on the EU).

5.3 Implications for Practice
The findings suggest that reducing the use of some common FRM tools could help firms
improve their operational efficiency. That said; this could change if EU Insurance Regulators
fully recognise the benefits of risk mitigation techniques in Regulatory Capital requirements (which they have now done, as from 1 January 2016, so FRM determinants should be explored again in future). Long-term solutions to improve a firm’s efficiency could include moving an office from Central London (where around 30% of registered offices for firms are based) to Greater London or a regional location, or increasing Firm Size by either growing organically, or merging with other firms. The methods in this study could also be easily implemented by fellow practitioners to monitor efficiency of their firms versus competitors on an ongoing basis.

5.4 Research Limitations

There are a number of limitations that emerged as part of this research. These are summarised in turn below.

A general limitation of insurance efficiency research appears to be the emergence of UK companies making use of offshore outsourcing arrangements for operational purposes, thus making it difficult to measure their actual inputs (and therefore accurate efficiency scores) of some firms. The efficiency results of any insurance efficiency study should therefore be read with this limitation in mind. Another general limitation comes with the efficiency measurement approach, regardless of which one is chosen. The main limitation with the parametric approach appears to be the number of key assumptions that are required in the cost or production function (e.g. the distribution of the error term), while the main limitation of the non-parametric approach is the loss of the statistical qualities that you get with a parametric approach. Since a non-parametric (DEA) approach is used, it comes with the relevant limitation. An additional methodological limitation relates to the non-separability assumption in the two-stage DEA approach of exploring drivers of efficiency or
inefficiency. A recent study by Grant et al. (2017) includes support for the argument by Simar and Wilson (2011), which suggests that the main problem of the two-stage regression based DEA studies is that they pre-assume that the ‘separability assumption’ among the inputs/outputs and the control variables holds. Based on this assumption, Grant et al. (2017) suggest that these studies unrealistically assume that the support of the inputs/outputs used to produce the DEA estimates does not depend on the environmental/control variables used in the regression stage of the analysis. This is mitigated in this study by performing another of tests to ensure that the regression approach is statistically robust (i.e. multicollinearity and serial correlation tests).

Recent years have seen the rise of well-diversified Financial Services Groups, which – in addition to Life insurance – offer a number of other financial services. For example, one group offers asset management, life insurance and non-life insurance. It is therefore possible that some inefficiency at the life insurance entity might be caused by deliberate cross-subsidies to maximise efficiency at the group level.

There are a number of limitations associated with the earnings data used in this study. Firstly, the Mutuals Public Register and the Financial Services Register to do not appear to offer the same depth of historical registered office address data that can be found on the Companies House website. In this instance, it was assumed that the firm was based at the same registered office throughout the sample period. There were 35 firms in this study that had data collected from these registers, and some of these firms might therefore have inaccurate historical office location data, which in turn might lead to them having inaccurate

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70 An example is Aviva plc. Source: https://www.aviva.com/
earnings data allocated to them. Secondly, the registered office location might not necessarily be where the majority of a firm’s operations take place. For example, the registered office of Legal and General Assurance was in Central London throughout the data sample, but the bulk of their operations appear to have been based in Kingswood (Surrey, UK) in this period\textsuperscript{71}. This could therefore lead to some firms getting incorrect efficiency scores assigned to them, and could also affect the overall level of efficiency in the industry. Thirdly, a previous UK study by Hardwick et al. (2011) appears to have used a sub-section of ONS wage data (called \textit{Regional Trends}) that was specific to the financial sector, but also allowed for regional variation. This would have arguably been an ideal source for wage data in this study. However, that particular section of ONS data appears to have been discontinued in 2011\textsuperscript{72}, and is therefore not available for a significant part of the sample period. The data used is therefore considered to be the most appropriate data available. The final limitation relates to how the data is grouped, i.e. by local authority, and not strictly by postal town. Some office location earnings might therefore reflect a wider geographical area than just the postal town in question. For example, Borehamwood and Potters Bar both come under the Hertsmere local authority. That said, the benefit of being able to vary earnings by office location appears to far outweigh all these earnings-related limitations, given the role that labour costs have in the efficiency calculation, and the variety of earnings data by location. Data limitations also meant that only the impact of using or not using derivatives could be explored in the regression stage of the study, and not the extent of the use, which would have arguably been more valuable to practitioners. The extent of derivative use would require data of notional amounts for positions opened in a given year,\textsuperscript{71} Source: https://www.legalandgeneralgroup.com/media-centre/press-releases/archive?id=50345\textsuperscript{72} https://data.gov.uk/dataset/4d550211-015f-4e15-8339-da4bd0245ed3/regional-trends
as described by Shiu (2007). This data does not appear to be publicly available for the UK Insurance Industry, based on the regulatory returns data used in this study.

There are a number of ways of calculating the reinsurance ratio, and each comes with limitations. For example, a ratio based on claims or reserves in any given year, can potentially capture the impact of historical reinsurance arrangements, so potentially distorts the impact of reinsurance on efficiency in that year. On the other hand, using reinsurance premiums, which get past the historical data limitation, can potentially be distorted by unusual entries, which – based on one example looked at as part of this study – could be explained by firms needing to account for one-off transactions that cannot be captured anywhere else in the regulatory returns, so end up in the reinsurance premium line. The latter approach was considered to be more appropriate based on the literature review, so the relevant limitations apply. On the back of the reinsurance limitation, the cleansing of the data before the Efficiency Regression stage of the analysis meant that some firms in the first stage of the analysis were omitted from the second stage, with the total number of data points reducing from 1,117 in the first stage to 1,019 in the second stage. This was primarily due to some reinsurance ratios above 100%, as a result of the limitations associated with the chosen reinsurance ratio approach. This is not expected to materially alter the findings of the second stage, due to the large number of data points that remain.

The final limitation relates to the efficiency calculation model. One efficiency score was set to zero by the model, because it could not be computed based on the data provided. Sensitivity testing was done on both the efficiency score and the regression analysis, by setting this score to 100%, and this was found to have no impact on the overall findings, so
the data was left unaltered. This chapter concludes with the potential areas of future research.

5.5 Future Research

There are a number of potential future studies that have emerged as part of this study. Firstly, this study attempts to analyse the impact of all Financial and Risk Management tools where data was available via the chosen data source. However, there were other Financial and Risk Management areas that appear to be of interest to practitioners, but which cannot be investigated due to lack of data. For example, in practice, UK life insurance companies appear to be moving into alternative illiquid investments to seek higher returns for policyholders and shareholders, due to low rates of return in traditional assets, which have been driven by the low interest rate environment (as discussed in section 1.1.7). It would therefore have been useful to explore the impact of (say) the level of Equity Release Mortgages on cost efficiency, to investigate whether this more bespoke approach to investing significantly affects cost efficiency one way or another. This could be the subject of future research, if the necessary data becomes available.

Secondly, this study found that reinsurance negatively impacts cost efficiency, with derivative use also having a negative coefficient, but suggests that the regulatory capital regime could be a key contributor to how these two Financial and Risk Management tools are viewed from an efficiency perspective. The regulatory capital regime changed significantly on 1 January 2016, with the introduction of Solvency II, and this had an impact on how reinsurance and derivatives are viewed for regulatory capital purposes. A future study – when sufficient post-2016 data emerges – could re-examine the relationship between these two tools and cost efficiency. The future study could follow a similar
methodological approach to this study, and obtain data from similar sources (e.g. Standard and Poor’s are starting to collect Solvency II regulatory data\(^73\)).

Thirdly, chapter 4 includes a correlation of 40% between cost efficiency scores and the FTSE 100 index, and raises the question of whether cost efficiency since the most recent published results can be approximated by a combination of the published result and the (pure or adjusted) movement of a published index since that result. This is proposed as a subject of future research.

Fourthly, as with any purely empirical study, this study sheds some light on what the level of efficiency is in the industry, and what drives efficiency or inefficiency. What it does not do, is explore why some efficiency or inefficiency drivers behave the way they do, although it does make some suggestions. A future research project, using a qualitative approach that gets the views of practitioners – possibly through structured or semi-structured interviews – could help to explain why certain patterns or trends have been seen in the results.

Fifthly, previous UK-focussed efficiency studies in Life insurance appear to have focussed of efficiency or inefficiency drivers that required major changes to how a business was run, i.e. organisational form, corporate governance or distribution systems. Future research could explore the impact of efficiency or inefficiency drivers that could be implemented without major business changes, as this study has done with Financial and Risk Management. These drivers include Human Resource and Process Management or Product Pricing, which have

\(^{73}\) Source: https://www.spglobal.com/marketintelligence/en/campaigns/regulatory-solutions
been explored in other insurance markets, so lessons could be learnt from the relevant studies before applying them to the UK insurance market.

Finally, this study has focussed on Cost Efficiency in the Life Insurance Industry, and also looks at its component parts – namely technical and allocative efficiency, with consideration for scale efficiency done as part of choosing the appropriate Returns to Scale assumption (which – in this study – meant that scale efficiency scores did not need to be computed). However, this study does not explore the other two main categories of efficiency – namely Revenue and Profit efficiency - because the current focus on the industry appears to be on operational efficiency, in light of the challenging economic environment after the Global Financial Crisis. Future studies could therefore explore these additional efficiency categories when the industry focus shifts from operational efficiencies to other types of efficiency.
References
References


Academy of Management (AOM) Code of Ethics, 2006


Code of Ethics and Conduct, British Psychological Society, 2009


Dutta, A. and Sengupta, P. P. (2011) 'Efficiency measurement of indian life insurance industry in


Ethical Guidelines for Educational Research, British Education Research Association (BERA), 2011


Framework for Research Ethics, Economic and Social Research Council (ESRC), 2015


Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2009), 'Multivariate data analysis, 7th ed.', *Prentice Hall*


REFERENCES Linked references are availa', 38(6), pp. 856–864.


Kader, H. A. *et al.* (2014) ‘Cost efficiency and board composition under different takaful insurance


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Appendices
Appendix 1: STATA Syntax and Code for DEA

**STATA Command:**

```
dea_allocative CostofLabour CostofCapital = Claims InvestedAssets, model (cost) rts (vrs) unitvars( LabourUnit CapitalUnit )
```

**Program Code:**

```stata
*! version 1.0.0  26SEP2011
*! Author: Choonjoo Lee
capture program drop dea_allocative
program define dea_allocative, rclass
    version 10.0
/** Terms Description:
 *    ------------------------------
 *    * RTS: Return To Scale
 *    * CRS: Constant Return to Scale
 *    * VRS: Variant Return to Scale
 *    ------------------------------
 */

// syntax checking and validation-------------------------------
// input varlist = output varlist
// example:
//   dea_allocative Employee Area = Sales Profits, model(c) values(1 2)
//   dea_allocative Employee Area = Sales Profits, model(r) values(2 2)
// ------------------------------
// returns 1 if the first nonblank character of local macro `0' is a comma,
// or if `0' is empty.
// if replay() {
//   dis as err "ivars and ovars required."
//   exit 198
// }

// get and check invarnames
gettoken word 0 : 0, parse("=," )
while ~("word" == ":" | "word" == ":") {
    if ":word" == "," | "word" == "" { error 198
        local invarnames `invarnames' `word'
        gettoken word 0 : 0, parse("=," )
    }
} unab invarnames : `invarnames`
```
#del ;
syntax varlist(min=1) [if] [in] [using/],
    MODel(string)  // ignore case sensitive {COST|REVENUE|PROFIT}
[
    VALues(numlist >0)  //
    UNITVars(varlist numeric) // unit variables for unit values
    RTS(string)  // ignore case sensitive,[{CRS|CCR}|{BCC|VRS}]
    TOL1(real 1e-14)  // entering or leaving value tolerance
    TOL2(real 1e-8)    // B inverse tolerance: 2.22e-12
    TRACE               // Whether or not to do the log
    DETAIL
    SAVing(string)      // log file name
    REPLACE             // Whether or not to replace the log file
];
#del cr

local num_invar : word count `invarnames'
local i 1
while (`i'<=`num_invar') {
    local invarn : word `i' of `invarnames'
    local junk : subinstr local invarnames "`invarn" "", ///
        word all count(local j)
    if `j' > 1 {
        di as error ///
        "cannot specify the same input variable more than once"
        error 498
    }
    local i = `i' + 1
}

// default model - CRS(Constant Return to Scale)
if ("rts" == ") local rts = "CRS"
else {
    local rts = upper("rts")
    if ("rts" == "CCR") local rts = "CRS"
    else if ("rts" == "BCC") local rts = "VRS"
    else if (~("rts" == "CRS" | "rts" == "VRS")) {
        di as err "option rts allow for case-insensitive _c"
        di as err "CRS (eq CCR) or VRS (eq BCC) or nothing."
        exit 198
    }
}

if ("using" != ") use "using", clear
if (~("c(N)" > 0 & "c(k)" > 0)) {
    di as err "dataset required!"
    exit 198
}
// make value matrix, check invarnames count and values count as model
tempname vmat
local sizeof_values : list sizeof values
local sizeof_unitvars : list sizeof unitvars
if (`sizeof_values' > 0 & `sizeof_unitvars' > 0) {
    dis as err "values and unitvars cannot be used at the same time."
exit 198
}

if (`sizeof_values' > 0) {
    foreach value of nu
    {
        matrix `vmat' = (nullmat(`vmat'), `value')
    }
}
else if (`sizeof_unitvars' > 0){
    mkmat `unitvars', mat(`vmat')
} else {
    dis as err "values and unitvars should be used at least."
exit 198
}

local model = upper("\`model'\")
if ("\`model'\" == "C") local model = "COST";
else if ("\`model'\" == "R") local model = "REVENUE";
else if ("\`model'\" == "P") local model = "PROFIT";
if ("\`model'\" == "COST") {
    if (colsof(`vmat') != `num_invar') {
        di as error "the number of input variable the same with " _c
        di as error "the number of values in unitvars."
        error 498
    }
}
else if("\`model'\" == "REVENUE") {
    local num_outvar : list sizeof varlist
    if (colsof(`vmat') != `num_outvar') {
        di as error "the number of output variable should be " _c
        di as error "the same with the number of values in unitvars."
        error 498
    }
}
else if("\`model'\" == "PROFIT") {
    local num_outvar : list sizeof varlist
    if (colsof(`vmat') != \"num_invar\" + `num_outvar\") {
        di as error "cannot different the sum of " _c
        di as error "number of in/output variable and number of values."
        error 498
    }
}
else {
    di as err "option model allow for case-insensitive " _c
    di as err "{C|COST or R|REVENUE or P|PROFIT}"
    exit 198
}

// end of syntax checking and validation

set more off
capture log close dea_allocative
log using "dea_allocative.log", replace
text name(dea_allocative)
preserve
if ("`if'" != ""
    qui keep `if' `if' // filtering: keep in range [if exp]
}

if ("`model'" == "COST") {
    dea_cost, ivars(`invarnames') ovars(`varlist') rts(`rts') ///
        model(`model') unitcost(`vmat') tol1(`tol1') tol2(`tol2') ///
        `trace' `detail' saving(`saving') `replace'
}
else if("`model'" == "REVENUE") {
    dea_revenue, ivars(`invarnames') ovars(`varlist') rts(`rts') ///
        model(`model') unitprice(`vmat') tol1(`tol1') tol2(`tol2') ///
        `trace' `detail' saving(`saving') `replace'
}
else {
    // if("`model'" == "PROFIT")
    dea_profit, ivars(`invarnames') ovars(`varlist') rts(`rts') ///
        model(`model') unitvalue(`vmat') tol1(`tol1') tol2(`tol2') ///
        `trace' `detail' saving(`saving') `replace'
}

return add

restore, preserve
log close dea_allocative
end

***************************************************************************
*****
* DEA Cost - Data Envelopment Analysis Cost Model
***************************************************************************

*****
program define dea_cost, rclass
    #del ;
syntax , IVARS(string) OVARS(string) RTS(string) 
    MODEl(string) UNITCost(name)
[
    TOL1(real 1e-14) TOL2(real 1e-8)
    TRACE DETAIL SAVing(string) REPLACE
];
#del cr

preserve

// -----------------------------------------------------------------------

tempname dmuIn dmuOut frameMat
tempname dearslt minIn theta
mkDmuMat `ivars', dmumat(`dmuIn') sprefix("i")
mkDmuMat `ovars', dmumat(`dmuOut') sprefix("o")
local dmuCount = colsof(`dmuIn')
local minrank = 1
local detailYn = ("`detail'" != ") | ("`trace'" != ")

// 1. Get Min Input
mata: _l_mkframemat("model", "frameMat", "dmuin", "dmuout", "rts")
mata: _l_dealp ("model", "frameMat", "dmuin", "dmuout", "rts", ///
    "unitcost", `tol1', `tol2', "trace")
if (`detailYn') {
di as result "Min Cost DEA Result:
matrix `dearslt' = J(`dmuCount', 1, .), r(dealprslt) // rank column
mata: _setup_dearslt_names("dearslt", "dmuin", "dmuout")
matrix list `dearslt', noblank nohalf noheader f(%9.6g)
}

matrix `dearslt' = r(dealprslt)
local i = (2 + `dmuCount')
matrix `minIn' = `dearslt'[1...,`i'..(`i' + rowsof(`dmuin') - 1)]

// 2. Get Theta
local ort = "IN"
local stage = 1
local minsubscript = 0 // false
mata: _mkframemat("frameMat", "dmuin", "dmuout", ///
    "rts", "ort")
deamain `dmuin' `dmuout' `frameMat' `rts' `ort' `stage' ///
    `tol1' `tol2' `minsubscript' `trace'
matrix `dearslt' = r(deamainrslt)
matrix `theta' = `dearslt'[1...,1]

// 3. Calculate Cost
mata: _l_calc_cost("unitcost", "dmuin", "minIn", "theta", `detailYn')
matrix `dearslt' = r(mat)
// ------------------------------------------------------------------------
// REPORT
// ------------------------------------------------------------------------
di as result ""
di as input "options: RTS(`rts')"
di as result "`rts' DEA-Cost Efficiency Results:"
matrix list `dearslt', noblank nohalf noheader f(%9.6g)
if ("saving" != "") {
   restore, preserve
   save_result `dearslt' `saving' `replace'
}
return matrix dearslt = `dearslt'
restore, preserve
end
***************************************************************************
*****
* DEA Revenue - Data Envelopment Analysis Revenue Model
***************************************************************************
*****
program define dea_revenue, rclass
#del ;
syntax , IVARS(string) OVARS(string) RTS(string)
   MODel(string) UNITPrice(name)
   [   TOL1(real 1e-14) TOL2(real 1e-8)
       TRACE DETAIL SAVing(string) REPLACE
   ];
#del cr

preserve
// ------------------------------------------------------------------------
tempname dmuIn dmuOut frameMat
tempname dearslt maxOut eta
mkDmuMat `ivars', dmumat(`dmuin') sprefix("i")
mkDmuMat `ovars', dmumat(`dmuOut') sprefix("o")
local dmuCount = colsof(`dmuin')
   local minrank = 1
   local detailYn = (""detail" != "") | (""trace" != "")
// 1. Get Max Output
mata: _l_mkframemat("model", "frameMat", "dmuln", "dmuOut", "rts")
mata: _l_dealp("model", "frameMat", "dmuln", "dmuOut", "rts", ///
"unitprice", `tol1', `tol2', "trace")

if (`detailYn') {
        di as result "Max Price DEA Result:"
        matrix `dearslt' = J(`dmuCount', 1, .), r(dealprslt) // rank column
        mata: _setup_dearslt_names("dearslt", "dmuln", "dmuOut")
        matrix list `dearslt', noblank nohalf noheader f(%9.6g)
}

matrix `dearslt' = r(dealprslt)
local i = (2 + `dmuCount')
matrix `maxOut' = `dearslt'[1...,`i'..(`i' + rowsof(`dmuOut') - 1)]

// 2. Get Eta
local ort = "OUT"
local stage = 1
local minsubscript = 0 // false
mata: _mkframemat("frameMat", "dmuln", "dmuOut", ///
"rts", "ort")
deamain `dmuln' `dmuOut' `frameMat' `rts' `ort' `stage' ///
`tol1' `tol2' `minsubscript' `trace'
matrix `dearslt' = r(deamainslt)
matrix `eta' = `dearslt'[1...,1]

// 3. Calculate Cost
mata: _l_calc_revenue("unitprice", "dmuOut", "maxOut", "eta", `detailYn')
matrix `dearslt' = r(mat)

// ----------------------------------------------------------------------
// REPORT
// ----------------------------------------------------------------------
di as result ""
        di as input "options: RTS(`rts')"
        di as result "rts' DEA-Revenue Efficiency Results:"
        matrix list `dearslt', noblank nohalf noheader f(%9.6g)
        if ("saving" != "") {
                restore, preserve
                save_result `dearslt' `saving' `replace'
        }
        return matrix dearslt = `dearslt'

restore, preserve
end
program define dea_profit, rclass
#del ;
syntax , IVARS(string) OVARS(string) RTS(string) MODel(string) UNITValue(name) 
[ 
   TOL1(real 1e-14) TOL2(real 1e-8) 
   TRACE DETAIL SAVing(string) REPLACE 
]; 
#del cr 
preserve
// -----------------------------------------------------------------------------
tempname dmuIn dmuOut frameMat 
tempname dearslt
mkDmuMat `ivars', dmumat(`dmuIn') sprefix("i") 
mkDmuMat `ovars', dmumat(`dmuOut') sprefix("o") 
local dmuCount = colsof(`dmuIn') 
local minrank = 1 
local detailYn = ("`detail'' != ") | ("`trace'' != ")

// 1. Get Max Profit 
mata: _l_mkframemat("model", "frameMat", "dmuin", "dmuout", "rts")
mata: _l_dealp ("model", "frameMat", "dmuin", "dmuout", "rts", ///
"unitvalue", `tol1’, `tol2’, "trace")
if (`detailYn') {
   di as result "Max Profit DEA Result:" 
   matrix `dearslt' = J(`dmuCount', 1, .), r(dealprslt) // rank column 
mata: _setup_dearslt_names(‘dearslt’, ‘dmuin’, ‘dmuout’) 
   matrix list `dearslt', noblank nohalf noheader f(%9.6g)
}

matrix `dearslt' = r(dealprslt)

// 2. Calculate Profit 
mata: _l_calc_profit(“unitvalue”, “dmuin”, “dmuout”, ///
“dearslt”, `detailYn’) 
matrix `dearslt' = r(mat)

// -----------------------------------------------------------------------------
// REPORT

216
di as result ""

di as input "options: RTS(`rts')"

di as result "`rts' DEA-Profit Efficiency Results:"

matrix list `dearslt', noblank nohalf noheader f(%9.6g)

if ("saving" !== "") {
    restore, preserve
    save_result `dearslt' `saving' `replace'
    }
return matrix dearslt = `dearslt'

restore, preserve

end

***************************************************************************
*****
* Save Result
***************************************************************************
*****

program define save_result, rclass
    args dearslt saving replace

    // if the saving file exists and replace option not specified,
    // make the backup file.
    if ("replace" == "") {
        local dotpos = strpos("saving",".")
        if (`dotpos' > 0) {
            mata: _file_exists("saving")
        }
        else {
            mata: _file_exists("saving.dta")
        }
    }
if (r(fileexists)) {
    local curdt = subinstr("c(current_date)", " ", "", .) + /*
        */ subinstr("c(current_time)", ":", "", .)
    if (`dotpos' > 0) {
        #del ;
        local savefn = substr("saving", 1, `dotpos' - 1) +
            "_bak_`curdt" +
            substr("saving","dotpos", .);
        #del cr
        qui copy "saving" "savefn", replace
    }
    else {
        local savefn = "saving_bak_`curdt" + ".dta"
        qui copy "saving.dta" "savefn", replace
    }
}
svmat `dearslt', names(eqcol)
capture {
    renpfix _
    renpfix CUR cur_
    renpfix TECH tech_
    renpfix MIN min_
}
capture save `saving', replace
end

***************************************************************************
*****
* DEA Main - Data Envelopment Analysis Main
***************************************************************************
*****
program define deamain, rclass
    args dmuIn dmuOut frameMat rts ort stage tol1 tol2 minsubscript trace

    tempname efficientVec deamainrslt

    // stage step 1.
    if ("trace" == "trace") {
        di _n(2) as txt "RTS(`rts') ORT(`ort') 1st stage."
    }
    mata: _dealp("frameMat", "dmuln", "dmuoOut", "rts", "ort", //
        1, `tol1', `tol2', "minsubscript", "efficientVec", "trace")
    matrix `deamainrslt' = r(dealprslt)

    // stage step 2.
    if ("stage" == "2") {
        if ("trace" == "trace") {
            di _n(2) as txt "RTS(`rts') ORT(`ort') 2nd stage."
        }
        matrix `efficientVec' = `deamainrslt'[1...,1]

        mata: _dealp("frameMat", "dmuln", "dmuoOut", "rts", "ort", //
            2, `tol1', `tol2', "minsubscript", "efficientVec", "trace")
        matrix `deamainrslt' = r(dealprslt)
    }

    return matrix deamainrslt = `deamainrslt'
end

***************************************************************************
*****
* Data Import and Conversion

*****

// Make DMU Matrix

program define mkDmuMat
    #del ;
    syntax varlist(numeric) [if] [in], DMUmat(name)
    [SPREfix(string)]
    ;
    #del cr

    qui ds
    // variable not found error
    if ("varlist" == ") {
        di as err "variable not found"
        exit 111
    }

    // make matrix
    mkmat `varlist' `if' `in', matrix(`dmumat') rownames(dmu)
    matrix roweq `dmumat' = "dmu"
    matrix coleq `dmumat' = `=lower("sprefix") + "slack"
    matrix `dmumat' = `dmumat''
end

// Start of the MATA Definition Area

version 10
mata:
    mata set matastrict on

    //----------------------------------------------------------------------------
    // Internal mata and stata combination.
    //----------------------------------------------------------------------------

    /**
     * calculate min cost
     */

    function _l_calc_cost(
        string scalar unitCost,
        string scalar dmuln,
        string scalar minln,
        string scalar theta,
        real scalar detail
    )
    {
        real matrix UC, DI, MI, TT // input
        real matrix TI, CC, TC, MC // cost calculate result

        //...
real matrix CCR, TCR, MCR // sum of cost calculate result
real matrix OE, AE, TE, FR // cost efficiency final result

string matrix DMU_CS // dmu column stripes
string matrix FR_CS // ce final result matrix column stripes
string matrix FR_RS // ce final result matrix row stripes
string matrix CS // temp column stripes

// input
UC = st_matrix(unitCost)
DI = st_matrix(dmuIn)'
MI = st_matrix(minIn)
TT = st_matrix(theta)

// cost calculate result
TI = TT:*DI // Thechnical Input
CC = UC:*DI // Current Cost
TC = UC:*TI // Technical Cost
MC = UC:*MI // Min Cost

// sum of cost calculate result
CCR = rowsum(CC)
TCR = rowsum(TC)
MCR = rowsum(MC)

// cost efficiency result
OE = (MCR:/CCR) // Overall Efficiency
AE = (MCR:/TCR) // Allocative Efficiency
TE = (TCR:/CCR) // Technical Efficiency

// final result
FR = (DI, CCR, TT, TI, TCR, MI, MCR, OE, AE, TE)

if (detail) {
    printf("\n(res)Input:\n")
    printf("\n(res)Unit Cost:\n"); UC
    printf("\n(res)DMU In:\n"); DI
    printf("\n(res)Min In:\n"); MI
    printf("\n(res)Theta:\n"); TT

    printf("\n(res)Temp Result:\n");
    printf("\n(res)Current Cost:\n"); CC
    printf("\n(res)Technical Cost:\n"); TC
    printf("\n(res)Min Cost:\n"); MC

    printf("\n(res)Final Result:\n"); FR
}
// return result
st_matrix("r(mat)", FR)

// ----------------------------------------------------------------------
DMU_CS = st_matrixrowstripe(dmuIn)
FR_RS = st_matrixcolstripe(dmuIn)

CS = DMU_CS\("","cost")
replaceSubmat(CS, 1, 1, J(rows(CS), 1, "CUR"))
FR_CS = CS;

CS = ("","theta")\DMU_CS\("","cost")
replaceSubmat(CS, 1, 1, J(rows(CS), 1, "TECH"))
FR_CS = FR_CS\CS

CS = DMU_CS\("","cost")
replaceSubmat(CS, 1, 1, J(rows(CS), 1, "MIN"))
FR_CS = FR_CS\CS

FR_CS = FR_CS\("","OE")\("","AE")\("","TE")

// name the row and column of dea result matrix
st_matrixrowstripe("r(mat)", FR_RS)
st_matrixcolstripe("r(mat)", FR_CS)
}

/**
 * calculate max revenue
 */
function _l_calc_revenue(
    string scalar unitPrice,
    string scalar dmuOut,
    string scalar maxOut,
    string scalar eta,
    real scalar detail )
{
    real matrix UP, DO, MO, ET // input
    real matrix TO, CP, TP, MP // revenue calculate result
    real matrix CPR, TPR, MPR // sum of revenue calculate result
    real matrix OE, AE, TE, FR // revenue efficiency final result

    string matrix DMU_CS // dmu column stripes
    string matrix FR_CS // ce final result matrix column stripes
    string matrix FR_RS // ce final result matrix row stripes
    string matrix CS // temp column stripes

    // input
UP = st_matrix(unitPrice)
DO = st_matrix(dmuOut)'
MO = st_matrix(maxOut)
ET = st_matrix(eta)

// cost calculate result
TO = ET:*DO // Thechnical Output
CP = UP:*DO // Current Price
TP = UP:*TO // Technical Price
MP = UP:*MO // Max Price

// sum of cost calculate result
CPR = rowsum(CP)
TPR = rowsum(TP)
MPR = rowsum(MP)

// cost efficiency result
OE = (CPR:/MPR) // Overall Efficiency
AE = (TPR:/MPR) // Allocative Efficiency
TE = (CPR:/TPR) // Technical Efficiency

// final result
FR = (DO, CPR, ET, TO, TPR, MO, MPR, OE, AE, TE)
if (detail) {
    printf("\n{res}Output:
")
    printf("\n{res}Unit Price:
"); UP
    printf("\n{res}DMU Out:
"); DO
    printf("\n{res}Max Out:
"); MO
    printf("\n{res}Eta:
"); ET

    printf("\n{res}Temp Result:
");
    printf("\n{res}Current Price:
"); CP
    printf("\n{res}Technical Price:
"); TP
    printf("\n{res}Max Price:
"); MP

    printf("\n{res}Final Result:
"); FR
}

// return result
st_matrix("r(mat)", FR)

// ---------------------------------------------------------------
DMU_CS = st_matrixrowstripe(dmuOut)
FR_RS = st_matrixcolstripe(dmuOut)
CS = DMU_CS\("","price")
replacesubmat(CS, 1, 1, J(rows(CS), 1, "CUR"))
FR_CS = CS;

CS = ('"","eta")\DMU_CS ('"","price")
replacesubmat(CS, 1, 1, J(rows(CS), 1, "TECH"))
FR_CS = FR_CS\CS

CS = DMU_CS ('"","price")
replacesubmat(CS, 1, 1, J(rows(CS), 1, "MAX"))
FR_CS = FR_CS\CS

FR_CS = FR_CS\("","OE")\("","AE")\("","TE")

// name the row and column of dea result matrix
st_matrixrowstripe("r(mat)", FR_RS)
st_matrixcolstripe("r(mat)", FR_CS)
}

/**
 * calculate max profit
 */
function _l_calc_profit(
    string scalar unitValue,
    string scalar dmuIn,
    string scalar dmuOut,
    string scalar dearslt,
    real scalar detail )
{
real matrix UV, DI, DO, DR // input: Unit Value, DMU In/Out, DEA Result
real matrix UC, UP, CP // Unit Cost, Unit Price, Current Profit
real matrix MI, MC // Min In, Min Cost
real matrix MO, MR, MP // Max Out, Max Revenue, Max Profit
real matrix CPR, MCR, MRR // Current Profit Result, Min Cost Result,
                         // Max Revenue Result
real matrix OE, FR // result: Overall Efficiency, Final Result

string matrix FR_CS // ce final result matrix column stripes
string matrix FR_RS // ce final result matrix row stripes
string matrix CS // temp column stripes

real scalar dmus, invars, outvars, vars

// input
UV = st_matrix(unitValue)
DI = st_matrix(dmuIn)
DO = st_matrix(dmuOut)
DR = st_matrix(dearslt)

dmus = cols(DI)
invars = rows(DI)
outvars = rows(DO)
vars = invars + outvars
if (vars != cols(UV)) {
    _error(3200, sprintf("%s%s",
                        "size of in/out of dmu and size of unit values ",
                        "are not match!" )))
}

UC = UV[,1..invars]
UP = UV[,1+invars..vars]
CP = (UV' :* (-DI \ DO))'

DR = DR[,2..1+dmus]
DR = ((DI \ DO)*(DR'))' // restore

MI = DR[,1..invars]
MO = DR[,1+invars..vars]

// profit calculate result
MC = UC :* MI
MR = UP :* MO

// sum of profit calculate result
CPR = rowsum(CP)
MCR = rowsum(MC)
MRR = rowsum(MR)

// profit efficiency result
MP = MRR : - MCR
OE = CPR : / MP

// final result
FR = (MO, MRR, MI, MCR, MP, CPR, OE)

// Logging
if (detail) {
    "Output:"
    "Unit Value."; UV
    "Unit Cost."; UC
    "Unit Profit."; UP
    "Current Profit."; CP

    "DMU In."; DI
    "DMU Out."; DO}
"DEA Result:"; DR
"Min In:"; MI
"Max Out:"; MO

"Temp Result:";
"Min Cost:"; MC
"Max Revenue:"; MR

"Final Result:"; FR
}

// return result
st_matrix("r(mat)", FR)

// --------------------------------------------------------------
FR_RS = st_matrixcolstripe(dmuIn)
CS = st_matrixrowstripe(dmuOut)
replacesubmat(CS, 1, 1, J(rows(CS), 1, "MAX_H"))
FR_CS = CS("MAX","revenue");

CS = st_matrixrowstripe(dmuIn)
replacesubmat(CS, 1, 1, J(rows(CS), 1, "MIN_H"))
FR_CS = FR_CS\CS("MIN","cost");

FR_CS = FR_CS\("MAX", "profit")\("CUR","profit")\("", "OE")

// name the row and column of dea result matrix
st_matrixrowstripe("r(mat)", FR_RS)
st_matrixcolstripe("r(mat)", FR_CS)
}

/**
 * make frame matrix and set matrix value at the param frameMat
 * rts - return to scale, ort - orientation
 */
function _l_mkframemat( 
    string scalar model, 
    string scalar frameMat, 
    string scalar dmuIn, 
    string scalar dmuOut, 
    string scalar rts ) 
{
    real matrix F, DI, DO
    real scalar dmus, variables, slackins, slackouts
    real scalar frows, fcols

\[ DI = st\_matrix(dmuIn) \]
\[ DO = st\_matrix(dmuOut) \]
if \((\text{cols}(DI) \neq \text{cols}(DO))\) {
    _error(3200, "in and out count of dmu is not match!")
}

dmus = \text{cols}(DI) \quad \text{or} \quad \text{cols}(DO), \quad \text{because} \quad \text{cols}(DI) = \text{cols}(DO)
slackins = \text{rows}(DI); \quad \text{slackouts} = \text{rows}(DO)

if \((\text{model} == \"\text{COST}\")\) \text{variables} = \text{slackins}
else if \((\text{model} == \"\text{REVENUE}\")\) \text{variables} = \text{slackouts}
else \text{variables} = 0 // \text{if} \((\text{model} == \"\text{PROFIT}\")\)

if \((\text{rts} == \"\text{CRS}\")\) {
    // target coefficient\backslash slackins\backslash slackouts
    frows = 1 + \text{slackins} + \text{slackouts}
    // target coefficient, \theta, \text{dmus}, \text{slackins}, \text{slackouts}, \text{rhs}
    fcols = 1 + 1 + \text{dmus} + \text{variables} + \text{slackins} + \text{slackouts} + 1
}
else if \((\text{rts} == \"\text{VRS}\")\) {
    // target coefficient\backslash slackins\backslash slackouts\backslash sum of lamda
    frows = 1 + \text{slackins} + \text{slackouts} + 1
    // target coefficient, \theta, \text{dmus}, \text{variables}, \text{slackins}, \text{slackouts}, \text{rhs}
    fcols = 1 + 1 + \text{dmus} + \text{variables} + \text{slackins} + \text{slackouts} + 1
}
else {
    _error(3498, "invalid rts option."
}

// make frame matrix for CRS(CCR)
F = J(frows, fcols, 0)
F[1, 1] = 1
replacesubmat(F, 2, 3, DI)
replacesubmat(F, 2+slackins, 3, DO)
if \((\text{model} == \"\text{COST}\")\) {
    replacesubmat(F, 2, 3+dmus, -I(\text{variables}))
    replacesubmat(F, 2, 3+dmus+variables, I(\text{slackins}))
    replacesubmat(F, 2+slackins, 3+dmus+variables+slackins, -I(\text{slackouts}))
}
else if \((\text{model} == \"\text{REVENUE}\")\) {
    replacesubmat(F, 2+slackins, 3+dmus, -I(\text{variables}))
    replacesubmat(F, 2, 3+dmus+variables, I(\text{slackins}))
    replacesubmat(F, 2+slackins, 3+dmus+variables+slackins, -I(\text{slackouts}))
}
else { // if \((\text{model} == \"\text{PROFIT}\")\)
    replacesubmat(F, 2, 3+dmus, I(\text{slackins}))
    replacesubmat(F, 2+slackins, 3+dmus+slackins, -I(\text{slackouts}))
}
// adjustment
if (rts == "VRS") {
    replacesubmat(F, frows, 3, J(1, dmus, 1))
    F[frows,fcols] = 1
}

// return result
st_matrix(frameMat, F)
}

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// Internal mata only.
//-------------------------------------------------------------

/**
 * DEA Loop - Data Envelopment Analysis Loop for DMUs
 */
function _l_dealp (string scalar model,
                    string scalar frameMat,
                    string scalar dmuIn,
                    string scalar dmuOut,
                    string scalar rts,
                    string scalar valueMat,
                    real scalar tol1,
                    real scalar tol2,
                    string scalar trace )
{
    real matrix F, DI, DO, M, VARS, LPRSLT, DEALPRSLT, ARTIF, VM, RVM
    real scalar dmus, slacki
    ns, slackouts, slacks, artificials, artificialrow
    real scalar frows, fcols, i, dmui, variables, minYn, vari
    real colvector effvec, slackidx
    string scalar tracename

    struct BoundCond matrix boundF, boundM
    struct LpParamStruct scalar param

    F  = st_matrix(frameMat)
    DI = st_matrix(dmuIn)
    DO = st_matrix(dmuOut)
    if (cols(DI) != cols(DO)) {
        _error(3200, "in and out count of dmu is not match!")
    }
    if (!(rts == "CRS" || rts == "VRS")) {
        _error(3498, "rts must be one of CRS, VRS")
    }
    VM = st_matrix(valueMat)
// basic value setting for artificial variables
frows = rows(F); fcols = cols(F)
dmus = cols(DI) // or cols(DO), because cols(DI) == cols(DO)
    if (rows(VM) != dmus) {
        VM = J(dmus, 1, VM);
    }

slackins = rows(DI); slackouts = rows(DO)
if (model == "COST") {
    minYn = 1 // minimized
    variables = slackins
}
else if (model == "REVENUE") {
    minYn = 0 // maximized
    variables = slackouts
}
else { // if (model == "PROFIT")
    minYn = 0 // maximized
    variables = 0
}

tracename = rts

// define number of slacks by rts
slacks = variables + slackins + slackouts

// define number of artificials by rts, ort, stage
if (rts == "CRS") {
    artificials = slackouts; artificialrow = 2+slackins;
}
else if (rts == "VRS") {
    artificials = slackouts+1; artificialrow = 2+slackins
}
else { // if (model == "PROFIT")
    artificials = 0; artificialrow = 0
}

boundF = J(1, fcols, BoundCond());
    // set the boundary for the efficiency variable(\(\theta, \eta\)):
    // -\(\text{INFINITE}\) <= \(\theta, \eta\) <= \(\text{INFINITE}\)
    boundF[1,2].val = 0; boundF[1,2].lower = 0; boundF[1,2].upper = .

    // set boundary for the weight variable(\(\lambda, \mu\)):
// 0 <= weight <= INFINITE
for (i=3; i<dmus+3; i++) {
    boundF[1,i].val = 0; boundF[1,i].lower = 0; boundF[1,i].upper = .
}

// set boundary for the non-structural variable(slack, artificial).
// 0 <= slacks and atrificials <= INFINITE
for (i=dmus+3; i<fcols; i++) {
    boundF[1,i].val = 0; boundF[1,i].lower = 0; boundF[1,i].upper = .
}

// liststruct(boundF); // for debug

// set the lp's parameters
param.rts            = rts
param.isin           = minYn // min
param.stagestep      = 1 // 1 step
param.dmus           = dmus
param.slacks         = slacks
param.artificials    = artificials
param.tol1           = tol1
param.tol2           = tol2
param.ismins subscript = 0 // false
param.trace          = trace

// liststruct(param); // for debug

DEALPRSLT = J(0, 1+ dmus + slacks, 0)
for (dmui=1; dmui<=dmus; dmui++) {
    M = F; boundM = boundF
    if (model == "COST") {
        replacesubmat(M, 2+slackins, fcols, DO[,dmui])
    }
    else if (model == "REVENUE") {
        replacesubmat(M, 2, fcols, DI[,dmui])
    }
    else { // if (model == "PROFIT")
        replacesubmat(M, 2, fcols, DI[,dmui])
        replacesubmat(M, 2+slackins, fcols, DO[,dmui])
    }

    // execute LP
    VARS   = lp_phase1(M, boundM, dmui, tracename, param)
    if (VARS[1,1] == .) {
        LPRSLT = J(1, cols(DEALPRSLT), .)
    }
    else {
        if (model != "PROFIT") {
            vari = dmus + 2 // variable start index
        }
    }
}
for (i = 1; i <= variables; i++) {
    M[1,] = M[1,] + ((VARS == vari++) * VM[dmui,i])
}

LPRSLT = l_lp_phase2(M, boundM, VARS, dmui, tracename, param);

}  // if (model != "PROFIT")

else { // if (model != "PROFIT")
    vari = 2  // dmu start index
    RVM = -VM[dmui,1..slackins], VM[dmui,1+slackins::cols(VM)]
    RVM = colsum(RVM' :* F[2..1+slackins+slackouts,3..2+dmus])
    for (i = 1; i <= dmus; i++) {
        M[1,] = M[1,] + ((VARS == vari++) * RVM[1,i])
    }

    LPRSLT = l_lp_phase2(M, boundM, VARS, dmui, tracename, param);
}

DEALPRSLT = DEALPRSLT \ LPRSLT

}

st_matrix("r(dealprslt)", DEALPRSLT)

}

real matrix function l_lp_phase2 ( 
real matrix M,
struct BoundCond matrix boundM,
real matrix VARS,
real scalar dmui,
string scalar aTracename,
struct LpParamStruct scalar param ) 
{

real matrix orgVARS, LPRSLT
real scalar j, phase
real vector slackidx
string scalar tracename, msg
struct LpResultStruct scalar lpresult

orgVARS = VARS

tracename = aTracename + "-PII"
if (param.trace == "trace") {
    displayas("txt")
    printf("\n---------[PHASE II]---------")
    printf("\n[DMUi=%g]%s: initialize matrix.\n", dmui, tracename); M
    printf("\n[DMUi=%g]%s: VARS.\n", dmui, tracename); VARS
}
phase = 2
lpresult = lp(M, boundM, VARS, dmui, phase, tracename, param)

// -----------------------------------------------------------------------------
// phase 2 final.
// -----------------------------------------------------------------------------
if(lpresult.rc) {
    LPRSLT = J(1, 1+param.dmus+param.slacks, .)
}
else {
// lpresult = theta(1) + dmus + slacks
    LPRSLT = J(1, 1+param.dmus+param.slacks, 0)
    for (j=1; j<=rows(lpresult.XB) ; j++) {
        if (VARS[1,j+1] > 0) LPRSLT[1, VARS[1,j+1]] =lpresult.XB[j, 1]
    }
}

if (param.trace == "trace") {
    msg = sprintf("[DMUi=%g]%s-FINAL", dmui, tracename);
    printf("\n%s: original VARS.\n", msg); orgVARS
    printf("\n%s: VARS.\n", msg); VARS
    printf("\n%s: XB.\n", msg); lpresult.XB
    printf("\n%s: LPRSLT.\n", msg); LPRSLT
}

return(LPRSLT)
}

end
// End of the MATA Definition Area ---------------------------------------------
Appendix 2: STATA output the SFA approach

Definitions of data inputs:

- \( \ln_{\text{TCM}} \) is the natural log of the sum of the Total Cost Components summarised in Section 4.2.1 (Table 4-3).
- \( \ln_{\text{labor}} \) is the natural log of the cost of labour summarised in Section 4.2.1 (Table 4-3).
- \( \ln_{\text{CoC}} \) is the natural log of the cost of capital summarised in Section 4.2.1 (Table 4-3).
- \( \ln_{\text{assets}} \) is the natural log of the invested assets summarised in Section 4.2.1 (Table 4-3).

\[
\text{ln}_{\text{TCM}} = \ln_{\text{labor}} + \ln_{\text{CoC}} + \ln_{\text{assets}}
\]

```
. frontier ln_TCM ln_labor ln_CoC ln_claims ln_assets, cost
Iteration 0:  log likelihood = -1665.1251
Iteration 1:  log likelihood = -1660.9726
Iteration 2:  log likelihood = -1660.7467
Iteration 3:  log likelihood = -1660.7457
Iteration 4:  log likelihood = -1660.7457

Number of obs   =  1,117
Wald chi2(4)    =  3995.86
Log likelihood  = -1660.7457  Prob > chi2    =  0.0000

\[
\begin{array}{lcccccc}
\text{ln}_{\text{TCM}} & \text{Coeff.} & \text{Std. Err.} & z & P>|z| & [95\% \text{ Conf. Interval}] \\
\hline
\text{ln}_{\text{labor}} & -.3028528 & .0854708 & -3.54 & 0.000 & -.4703726 & -.135333 \\
\text{ln}_{\text{CoC}} & .5286531 & .034791 & 15.20 & 0.000 & .4604639 & .5968422 \\
\text{ln}_{\text{claims}} & -.0203436 & .0350826 & -0.58 & 0.562 & -.0891043 & .0484172 \\
\text{ln}_{\text{assets}} & .7805304 & .0396585 & 19.68 & 0.000 & .7028011 & .8582597 \\
\text{-cons} & 2.13298 & .689067 & 3.10 & 0.002 & .7827481 & 3.483213 \\
\hline
\text{/lnsig2v} & -.1777789 & .0937017 & -1.90 & 0.058 & -.3614308 & .005873 \\
\text{/lnsig2u} & -.1469574 & .2456432 & -0.60 & 0.550 & -.6284092 & .334943 \\
\hline
\text{sigma}_v & .9149467 & .042866 & & & .8346729 & 1.002941 \\
\text{sigma}_u & .9291559 & .1141204 & & & .7303696 & 1.182046 \\
\text{sigma2} & 1.700458 & .156727 & & & 1.393279 & 2.007638 \\
\text{lambda} & 1.01553 & .1505744 & & & .7204097 & 1.31065 \\
\hline
\text{LR test of sigma_u=0: chibar2(01) = 8.99} & \text{Prob} \geq \text{chibar2} = 0.001
\end{array}
```

LR test of sigma_u=0: \( chibar2(01) = 8.99 \)  Prob >= chibar2 = 0.001

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Appendix 3: STATA Code for the Simar & Wilson approach

***************************************************************************
*************************************
****************
** SIMAR & WILSON (2007) TWO-STAGE EFFICIENCY ANALYSIS
***************************************************************************
***************************************************************************
***********************************
******************
*! version 2.20 2018-11-06 ht
*! version 2.19 2018-04-20 ht
*! version 2.18 2018-04-07 ht
*! version 2.17 2018-03-24 ht
*! version 2.16 2018-03-13 ht
*! version 2.15 2018-01-05 ht
*! version 2.14 2017-11-27 ht
*! version 2.13 2017-09-19 ht
*! version 2.12 2017-09-15 ht
*! version 2.11 2017-09-07 ht
*! version 2.10 2017-08-06 ht
*! version 2.9 2017-07-22 ht
*! version 2.8 2017-06-30 ht
*! version 2.7 2017-06-19 ht
*! version 2.6 2017-06-14 ht
*! version 2.5 2017-06-08 ht
*! version 2.4 2017-06-01 ht
*! version 2.3 2017-04-13 ht
*! version 2.2 2017-01-17 ht
*! authors Harald Tauchmann & Oleg Badunenko
*! Simar & Wilson two-stage Efficiency Analysis

capture program drop simarwilson
program simarwilson, eclass
** CHECK VERSION (For Handling Unicode Variables) **
if `c(stata_version)'< 14.2 {
    local str "str"
    local substr "substr"
    local ustr ""
    local subinstr "subinstr"
    version 12
}
else {
    local str "ustr"
    local substr "usubstr"
    local ustr "ustr"
    local subinstr "usubinstr"
    version 14.2
}
if !replay() {
    quietly {
        ** SET DEFAULTS FOR # OF REPETITIONS **
        local defaultbcreps = 100
        local defaultreps = 1000
        ** STORE COMMANDLINE ENTRY **
        local cmd "simarwilson"
        local cmdline ""cmd" '*"
        ** SYNTAX DEFINITION **
        syntax anything(equalok) [if] [in] [pweight iweight], /*
        */ [REPS(integer `defaultreps')] [noUNIT] [noTWOsided] [LEVEL(real `c(level)') ] [DOTS]
        [SAVEAll(name)] [CiNormal] [BOOTstrap] [noCONstant] [noRTNORM] [OFFSET(varname)]
        [DIFFicult] [COLinear] [CONSTraints(passthru)] [TEChnique(passthru)] [ITERate(passthru)]
        [TOLERance(passthru)] [LTOLErance(passthru)] [NRTOLERance(passthru)]
        [FROM(passthru)] [CFORMAT(string asis)] [PFORMAT(string asis)] [VSQUISH] [noOMITted] [BASElevels] [TRNoisily]/*
        */ [ALGorithm(integer 1)] [INVert] [LOGscore] [noPRint] [noDEAPrint] [Rts(string)]
        [Base(string)] [BCReps(integer `defaultbcreps')] [REFERENCE(name)]
        [TEName(name)] [TEBC(name)] [BIASSte(name)] [BCSAVEAll(name)] [EXTOLERance(real 37.5)]
        ** TEMPORARY FILES, MATRICES, and VARIABLES **
        ** TEMPVARS **
        tempvar __tempid __tempwgh _rnn _yoff _iyy _truncfit
        _ntruncfit _yboot _esamp _deascore _indepmomis _deamark _reference
        _reference
        ** TEMPNAMES **
        tempname __borg __coef __sig __cov __bbm __bbias __rank __Cns
        __BB __VB __BM __cip __ndeao __nmdeao __nDearefo __cnps
        ** TEMPNAMES FOR PLUGIN **
        tempname __yobs __xobs __nO __nl __nobs __yref __xref __nref __rt __ba __ifqh
        __intovar __teB __MatStar __ystar __xstar __DEAB __DEABC __DEABIAS
        ** TEMPFILES **
        tempfile __resufile
        ** HANDLE MORE **
        local moreold `c(more)'
        set more off
        ** DISPLAY-FORMAT for WARNINGS **
        local ls = c(linesize)-7
        local lshl = c(linesize)-3
        ** PARSEING ANYTHING **
        gettoken deasyntax varlist : anything, parse("") match(paren) bind
        if ""paren" == "" {
            local varlist "deasyntax"
            local deasyntax ""
        }
        else {
            gettoken left right : deasyntax, parse("")
            if "right" != "" {
                display as error "(p 0 2 2 `ls')invalid syntax(p_end)"
            }
        }
    }
}

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exit 198

** CHECK VARLIST FOR MISPLACED CHARACTERS **
local mpcv = 0
foreach cc in "[" ]" !+ "\" ";&" %" "{ "{
    local mpc = `str`pos("varlist", "cc")
    local mpcv = `mpcv` + `mpc`
} if `mpcv` > 0 { display as error "(p 0 2 2 `ls`)invalid syntax or invalid names in {bf:`varlist'}(p_end)"
    exit 198
}

** CHECK FOR EMPTY VARLIST **
if ""varlist"" == ""
    local vlempty = 1
    if ""constant"" == "noconstant" {
        display as error "(p 0 2 2 `ls`)neither indepvars nor constant specified(p_end)"
        exit 198
    }
}
if "`deasyntax'" == "" & wordcount("varlist") == 1 & "`constant'" == "noconstant" {
    display as error "(p 0 2 2 `ls`)neither indepvars. nor constant specified(p_end)"
    exit 198
}

** PARSE DEA-SYNTAX **
local deasyntax : list retokenize local(deasyntax)
if "`deasyntax'" != "" & "`deasyntax'" != ""
    gettoken oispec refspec : deasyntax, parse("(") match(paren) bind
    if "`oispec'" != "" & "`refspec'" != "" {
        local oispec "`refspec'"
        local refspec ""
    }
    if "`refspec'" != "" {
        display as error "(p 0 2 2 `ls`)option (ref_outputs = ref_inputs) not allowed; `refspec' ignored(p_end)"
    }
    gettoken outps inps : oispec, parse("=")
    gettoken left inps : inps, parse("=")
    local outps : list uniq local(outps)
    local inps : list uniq local(inps)
    local nO = `ustr`wordcount("`outps'")
    local nI = `ustr`wordcount("`inps'")

** CHECK FOR OUTPUTS AND INPUTS BEING MUTUALLY EXCLUSIVE **
local oiintersec : list local(outps) & local(inps)
if "oiintersec" != "" {
    display as error "\(p 0 2 2 \text{'ls'}\)lists of outputs and inputs must be mutually exclusive\(p_{\text{end}}\)"
    exit 198
}

** CHECK FOR OUTPUT- AND INPUT-VARIABLES BEING DEFINED AND NUMERIC OR SYNTAX BEING INVALID **
cap confirm numeric variable `outps` `inps'
if _rc != 0 {
    display as error "\(p 0 2 2 \text{'ls'}\)invalid syntax or not defined or non-numeric variable(s) in \{bf:('oispec')}\(p_{\text{end}}\)"
    exit _rc
}

** CHECK FOR EMPTY INPUT- OR OUTPUT-LIST **
if `nO' <= 0 | `nl' <= 0 {
    display as error "\(p 0 2 2 \text{'ls'}\)at least one input and one output required\(p_{\text{end}}\)"
    exit 198
}

** HANDLE OPT. ALGORITHM **
if `algorithm' != 1 & `algorithm' != 2 {
    display as error "\(p 0 2 2 \text{'ls'}\)invalid value for option alg() specified; only 1 or 2 is allowed\(p_{\text{end}}\)"
    exit 198
}

if `algorithm' == 2 & "$\text{deasyntax}" == "" {
    display as error "\(p 0 2 2 \text{'ls'}\)algorithm #2 requires (outputs = inputs)\(p_{\text{end}}\)"
    exit 198
}

if `algorithm' == 1 {
    local alg2opt ""
    if `bcreps' != 100 {
        local alg2opt "$\text{alg2opt'} bcreps('bcreps')"
    }
    if "$\text{tebc}" != "" {
        local alg2opt "$\text{alg2opt'} tebc('tebc')"
    }
    if "$\text{biaste}" != "" {
        local alg2opt "$\text{alg2opt'} biaste('biaste')"
    }
    if "$\text{bcsaveall}" != "" {
        local alg2opt "$\text{alg2opt'} bcsaveall('bcsaveall')"
    }
    if "$\text{alg2opt'}" != "" & "$\text{print}" != "noprint" {
        display as error "\(p 0 2 2 \text{'ls'}\)warning: no bias-correction with alg. #1;\text{alg2opt'} ignored\(p_{\text{end}}\)"
    }
}
** HANDLE VARIABLES TO GENERATE **
if "tename" != "" & "deasyntax" != ""
    confirm new variable `tename'
}
if "tebc" != "" & "deasyntax" != "" & "algorithm" == "2"
    confirm new variable `tebc'
}
if "biaste" != "" & "deasyntax" != "" & "algorithm" == "2"
    confirm new variable `biaste'
}

** HANDLE TERADIAL OPTIONS IF NOT USED **
if "deasyntax" == ""
    local deaopt ""
if "rts" != ""
    local deaopt "deaopt rts(rts)"
}
if "base" != ""
    local deaopt "deaopt base(base)"
}
if "reference" != ""
    local deaopt "deaopt reference(reference)"
}
if "tename" != ""
    local deaopt "deaopt tename(tename)"
}
if "deaopt" != "" & "print" != "noprint"
    display as error "{p 0 2 2 `ls'}warning: external dea scores used;`deaopt' ignored{p_end}"
}

** HANDLE TERADIAL OPTIONS **
if "deasyntax" == ""
    if "rts" == ""
        local rts "CRS"
    }
    if upper(substr("rts",1,1)) == "C"
        local rts "CRS"
    }
    if upper(substr("rts",1,1)) == "N"
        local rts "NIRS"
    }
    if upper(substr("rts",1,1)) == "V"
        local rts "VRS"
    }
    if "base" == ""
        local base "output"
if upper(substr(`base',1,1)) == "O" {
    local base "output"
}
if upper(substr(`base',1,1)) == "I" {
    local base "input"
}
if "base" == "output" {
    if "invert" == "" {
        local unit "nounit"
    }
    else {
        local unit ""
    }
} else {
    if "base" == "input" {
        if "invert" == "" {
            local unit ""
        }
        else {
            local unit "nounit"
        }
    }
}
if `bcreps' < 1 {
    display as error "{p 0 2 2 `ls'}bcreps(`bcreps') too small for bias correction(p_end)"
    exit 498
}
if `bcreps' < 100 & "`print'' != "noprint" & "`algorithm'' == "2" {
    display as error "{p 0 2 2 `ls'}warning: bcreps(`bcreps') too small for meaningful bias correction(p_end)"
}

** HANDLE OPTION INVERT **
if "deasyntax" != "" {
    if "invert" == "" {
        local expinvert = 1
        local printinvert "Farrell"
    }
    else {
        local expinvert = -1
        local printinvert "Shephard"
    }
}
else {
    if "invert" != "" & "print" != "noprint" {


display as error "Warning: opt. invert has no effect with externally estimated scores; invert left-hand-side variable manually to switch from Farrell to Shepard efficiency(p_end)"
}
}
** HANDLE OPTION TRNOISILY **
if "trnoisily" != "" {
    local trn "noisily"
}
** DE-FACTOR-VARIABLEIZE VARLIST **
if "vempty" != "1" {
    local varlist : list uniq local(varlist)
    defvar 'varlist'
    local varlist2 "r(dfvl)"
}
** CHECK FOR NON-NUMERIC VARIABLES *
cap confirm numeric variable 'varlist2'
if _rc != 0 & "varlist2" != "" {
    display as error "non-numeric variable(s) in varlist {bf: `varlist2'}{p_end}
    exit _rc
}
** HANDLE OPTION TENAME **
if "tename" != "" {
    local savete "tename"
}
** HANDLE OPTION LOGSCORE **
if "logscore" != "logscore" {
    local trlim = 1
    local trlefte ""
} else {
    local trlim = 0
    local trlefte "exp"
}
** HANDLE OPTION NOTWOSIDED **
if ("twosided" == "notwosided") & (\algorithm == 2) & ("unit" == "") & ("print" != "noprint") {
    display as error "Warning: opt. notwosided not recommendable with alg. #2; in step 3.1 (alg. #2) sampling is from the twosided-truncated normal distribution(p_end)"
}
** CHECK FOR EXCESSIVE NUMBER OF INPUTS AND OUTPUTS **
if "deasyntax" != "" {
    mark `__deamark'
    markout `__deamark` `outps` `inps` `varlist2` `offset'
    if "if" == ""
        local iffill "if"
}
else {
    local iffill "if' &" 
}

if `nO' + `nI' >= r(N) {
    noi display as error "{p 0 2 2 `ls'}number of DMUs (`r(N)') must be larger than sum of number of outputs (`nO') and inputs (`nI')
{p_end}" 
    exit 409 
}

** HANDLE OPTION REFERENCE **
if "deasyntax" == "" {
    gen `__reference' = 1 
}
else {
    if "reference" == "" {
        gen `__reference' = 1 
    }

    else {
        cap egen `__creference' = group(`reference') 
        if _rc == 111 {
            display as error "{p 0 2 2 `ls'}invalid reference spec.; {bf:`reference'} not found{p_end}" 
            exit 111 
        }
        replace `__creference' = `__creference' - 1 
        cap tab `__creference' 
        if r(r) > 2 | _rc == 134 {
            display as error "{p 0 2 2 `ls'}invalid reference spec.; {bf:`reference'} not binary{p_end}" 
            exit 198 
        }
        if r(r) < 2 {
            display as error "{p 0 2 2 `ls'}no variation in {bf:`reference'}; opt. reference ignored{p_end}" 
            gen `__reference' = 1 
        }
    }
}
else {
    ** CHECK WETHER REFERENCE SET INCLUDES DMUs EXLUDED by IF or IN **
    count `in' `iffill` __deamark'==1 
    local nrefs = r(N) 
    count `in' `iffill` __deamark'==0 
    local nrefs0 = r(N) 
    count if (`__reference' == 1 & `__deamark'==1) 
    local nrefa = r(N) 
    if `nrefa' > `nrefs' & "print" != "noprint" {
        display as error "{p 0 2 2 `ls'}warning: simarwilson does not allow for ref. DMUs that are not included in the estimation sample{p_end}" 
    }

    if nO' + nI' >= r(N) {
        noi display as error "{p 0 2 2 `ls'}number of DMUs (r(N)) must be larger than sum of number of outputs (nO') and inputs (nI')
{p_end}" 
        exit 409 
    }

    ** HANDLE OPTION REFERENCE **
    if "deasyntax" == "" {
        gen __reference = 1 
    }

    else {
        if "reference" == "" {
            gen __reference = 1 
        }

        else {
            cap egen __creference = group(reference) 
            if _rc == 111 {
                display as error "(0 2 2 l's')invalid reference spec.; (bf:reference') not found(p_end)" 
                exit 111 
            }
            replace __creference = __creference - 1 
            cap tab __creference 
            if r(r) > 2 | _rc == 134 {
                display as error "(0 2 2 l's')invalid reference spec.; (bf:reference') not binary(p_end)" 
                exit 198 
            }
            if r(r) < 2 {
                display as error "(0 2 2 l's')no variation in (bf:reference'); opt. reference ignored(p_end)" 
                gen __reference = 1 
            }
        }
    }
}
if `nrefs' == 0 & `nrefs0' > 0 {
    display as error "{p 0 2 2 `ls'}reference set empty; opt. reference ignored\{p_end\}"
    gen `__reference' = 1
} else {
    if `nrefs' <= (\`nO' + \`nI') {
        display as error "{p 0 2 2 `ls'}number of reference DMUs (\`nrefs') must be larger than sum of number of outputs (\`nO') and inputs(\`nI'); opt. reference ignored\{p_end\}"
        gen `__reference' = 1
    } else {
        gen `__reference' = `__creference'
    }
}

** HANDLE LEVEL **
if `level' >= 10 & `level' <= 99.99 {
    local level = round(`level',0.01)
    local level = substr("level",1,5)
} else {
    if "print" != "noprint" {
        noisily display as error "{p 0 2 2 `ls'}warning: level(`level') not allowed, outside [10,99.99] interval\{p_end\}"
    }
    local level = `c(level)'
}

** CHECK NUMBER of REPS **
if `reps' < 2 {
    display as error "{p 0 2 2 `ls'}reps(`reps') too small for computing standard errors\{p_end\}"
    exit 498
} else {
    if ("cinormal" != "cinormal" & `reps' < `defaultreps') & "print" != "noprint" {
        display as error "{p 0 2 2 `ls'}warning: reps(`reps') too small for meaningful percentile CIs\{p_end\}"
    }
}

** HANDLE WEIGHT **
if "weight" != "" {
    gen double `__tempwgh` exp'
    local weight2 = substr("weight",1,2)
} else {
    local weight2 = `c(weight)'
}
gen `__tempwgh' = 1
local weight2 "pw"
}
local exp2 `\__tempwgh''
** HANDLE TRUNCREG OPTIONS **
local opttrunc "'constraints' 'collinear' 'noomitted' 'difficult'
'technique' 'tolerance' 'ntolerance' 'nonrtolerance' 'from''
local itetrunc "'iterate'"
** TOKENIZE VARLIST **
if "'deasyntax'" == "" {
  tokenize `varlist'
  local yy "'1''
  local xx : list local(varlist) - local(yy)
}
** HANDLE DEPENDENT VARIABLE **
if "'deasyntax'" == "" {
  foreach fo in "'##' '###' '.' " {
    local check = `str'pos("yy","fo")
    if `check' != 0 {
      if "'fo'" == "'##'" | "'fo'" == "'###'" {
        display as error "'{p 0 2 2 'ls'}depvar may not be an interaction'{p_end}'"
        exit 198
      }
    }
  }
}
** HANDLE OFFSET VARIABLE **
foreach fo in "'##' '###' '.' " {
  local check = `str'pos("offset","fo")
  if `check' != 0 {
    if "'fo'" == "'##'" | "'fo'" == "'###'" {
      display as error "'{p 0 2 2 'ls'}interactions not allowed in option offset()'{p_end}'"
      exit 101
    }
  }
}
} }

** DE-FACTOR-VARIABLEIZE VARLIST **

if "vempty" != "1" {
    defvar `varlist'
    local varlist2 "r(dfvl)"
}

** SELECT ESTIMATION SAMPLE **

gen `__tempid' = _n
preserve
if "if" != "" {
    keep `if'
}
if "in" != "" {
    keep `in'
}
keep `__tempid' `__tempwgh' `varlist2' `offset' `outps' `inps' `__reference'

** DROP MISSINGS **
cap drop `__deamark'
mark `__deamark'
markout `__deamark' `outps' `inps' `varlist2' `offset' `__reference'
keep if `__deamark' == 1
sort `__reference' `__tempid'

** EXECUTE TERADIAL to OBTAIN UN-CORRECTED DEA-SCORES **
if "deasyntax" != "" {
    teradial `outps' = `inps', rts(`rts') base(`base') tename(`__deascore')
    reference(`__reference')
    mata : st_numscalar("__nmdeao", colmissing(st_data(.,"__deascore")))
    mata : st_numscalar("__ndeao", colnonmissing(st_data(.,"__deascore")))
    if __ndeao <= 0 {
        di as error "{p 0 2 2 `ls'}data envelopment analysis failed{p_end}
        restore
        exit 498
    }
    if __nmdeao > 0 & "print" != "noprint" {
        local mnndeao = __nmdeao
        di as error "{p 0 2 2 `ls'}warning: estimation of scores failed for `mnndeao'
    }
    mata : st_numscalar("__ndearefo",
        colnonmissing((st_data(.,"__deascore"):/(st_data(.,"__reference")))))
    replace `__deascore' = (`__deascore')^(expinvert)
    keep if `__deascore' <.
    if savete != "" {
        ** SAVE DEA SCORE PERMANANTELY **
        gen double `savete' = `__deascore'
        label variable `savete' "printinvert"`base'-oriented efficiency score under `rts"
** FEED-IN DEA-SCORES **

local yy "__deascore"
local varlist : list local(__deascore) | local(varlist)
local xx : list local(varlist) - local(yy)

** CHECK DEPENDENT VARIABLE **

if "deasyntax" == "" & "print" != "noprint" {
    count if `yy' == 100
    local ny100 = r(N)
    count if `yy' > 25 & `yy' <= 100
    local sylarge = r(N)
    count if `yy' <.
    local sylarge = floor(100*`sylarge'/r(N))
}

    sum `yy' if `yy' <.
    if r(min)< 0 {
        if "deasyntax" == "" {
        display as error "nonpositive efficiency scores in {bf:`yy'}"{p_end}
        } else if "savete" != "" {
        display as error "nonpositive efficiency scores in {bf:`savete'}{p_end}
        } else {
        display as error "nonpositive efficiency scores found{p_end}"
        }
        restore
        exit 482
    }
        if "deasyntax" == "" & "print" != "noprint" {
        if (r(min) > 0 & r(max) == 100 | `ny100' > 0 | `sylarge' > 50) {
        display as error "warning: for `ny100' obs {bf:`yy'} = 100, for `sylarge'% of obs {bf:`yy'} > 25; check whether efficiency is inappropriately measured in percent; if so rescale var. {bf:`yy'}"{p_end}
        }
        }
        if r(min) < 1 & r(max) > 1 {
        if "unit" == "" & "print" != "noprint" {
            if "deasyntax" == "" {
            display as error "warning: values of {bf:`yy'} not bounded to unit interval{p_end}"
            } else if "savete" != "" {
            display as error "warning: values of {bf:`savete'} not bounded to unit interval{p_end}"
            } else {244
}
display as error "\{p 0 2 2 `ls'}warning: efficiency scores not bounded to unit interval\{p_end}"
}
    }
    if "`unit'' == "nounit" & "`print'' != "noprint" {
        display as error "\{p 0 2 2 `ls'}warning: \{bf:`yy'} values of \{bf:`yy'} not bounded to [1,+inf) interval\{p_end}"
    }
    else if "`savete'" != "" {
        display as error "\{p 0 2 2 `ls'}warning: values of \{bf:`savete'} not bounded to [1,+inf) interval\{p_end}"
    }
    else {
        display as error "\{p 0 2 2 `ls'}warning: efficiency scores not bounded to [1,+inf) interval\{p_end}"
    }
}

if (r(min) >= 0 & r(max) <= 1 & "`unit'' == "nounit" {
    local unit ""
}
if (r(min) >= 1 & "`unit'' == ""{
    local unit "nounit"
}

** TAKE LOG IF OPTION LOGSCORE **
if "`logscore'" == "logscore" {
    replace `yy' = log(`yy')
}

** RUN PRECEDING OLS REGRESSION **
if "`offset'" != "" {
    gen double `__yoff' = `yy' - `offset'
}
else {
    gen double `__yoff' = `yy'
}
cap reg `__yoff' `xx' ['weight2' = `exp2']

** DETERMINE SAMPLESIZE **
sum `exp2' if e(sample)
local wsall = r(sum)
local nnall = r(N)
sum `exp2' if e(sample) & `yy' == `trlim'
local wslim = r(sum)
local nnlim = r(N)
    if "`unit'' == "nounit" {
        sum `exp2' if e(sample) & `yy' < `trlim'
        local wsrirreg = r(sum)
        local nnirreg = r(N)
    }
else {
    sum `exp2' if e(sample) & `yy' > `trlim' & `yy' <.
    local wsigirreg = r(sum)
    local nniirreg = r(N)
}

** RUN INITIAL TRUNCATED REGRESSION **
if "`unit'" == ""
if ("`twosided'" == "notwosided") | ("`logscore'" == "logscore") {
    cap `trn' truncreg `yy' `xx' [`weight2' = `exp2'], ul(`trlim') `constant'
        offset(`offset') `opttrunc' `itetrunc'
} else {
    cap `trn' truncreg `yy' `xx' [`weight2' = `exp2'], ll(0) ul(1) `constant'
        offset(`offset') `opttrunc' `itetrunc'
} else {
    cap `trn' truncreg `yy' `xx' [`weight2' = `exp2'], ll(`trlim')
        `constant' offset(`offset') `opttrunc' `itetrunc'
} if _rc != 0 | e(converged) != 1 {
    if e(converged) != 1 {
        display as error "{p 0 2 2 `ls'}convergence not achieved in truncated regression{p_end}"
    } else {
        display as error "{p 0 2 2 `ls'}truncated regression failed{p_end}"
    }
    ereturn clear
    restore
if _rc != 0 {
    exit _rc
} else {
    exit 430
}
}

gen `__esamp' = 1 if e(sample)
local sig = e(sigma)
predict `__truncfit', xb
gen double `__ntruncfit' = `trlim' - `__truncfit'
matrix `__borg' = e(b)

** RECALCULATE SAMPLESIZE **
   sum `exp2' if e(sample)
local wgtsum = r(sum)
local tsamps = r(N)

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** CHECK FOR EXTREME LARGE VALUES OF PREDICTED EFFICIENCY VALUES **

if `algorithm' == 1 {
    local nolimdmu "& `yy' != `trlim''
}

if ""unit"" != "nounit" & (""twosided"" != "notwosided" | `algorithm' ==2) & ""logscore"" != "logscore" {
    count if max(abs(`__ntruncfit'),abs(`__ntruncfit' -1)) >= `extolerance'*`sig' & `__ntruncfit' <. `nolimdmu'
    local diextval "max(abs((1-xb)/sigma),abs((-xb)/sigma))"
}

else {
    count if abs(`__ntruncfit') > = `extolerance'*`sig' & `__ntruncfit' <. `nolimdmu'
    local diextval "abs((`trlim'-xb)/sigma)"
}

if r(N) > 0 {
    display as error "{p 0 2 2 `ls'}extreme values for fitted efficiency encountered: `diextval' > `extolerance' for at least one DMU; bootstrap likely to fail; consider changing specification and check for possible outlier(s){p_end}"
    ereturn clear
    restore
    exit 498
}

** EXTRACT "EX-POST" VARLIST **

local cn : colnames e(b)
local xx2 : subinstr local cn "_cons" "", all word
local xx2 : list retokenize xx2
if ""algorithm"" == "1" {
    ** TRANSFER RESULTS **
    local ic = e(ic)
    local k_eq = e(k_eq)
    local converged = e(converged)
    local rc = e(rc)
        local ll = e(ll)
    local df_m = e(df_m)
    local k_aux = e(k_aux)
    ** CHECK for CONSTRAINTS **
    if ""e(Cns)"" != "" {
        matrix `__Cns' = e(Cns)
        local iconstr "iconstr"
    }
}

** RUN SIMAR & WILSON BOOTSTRAPP **

local floop = 3-`algorithm'
** EXECUTE LOOP DEPENDING ON CHOICE of ALGORITHM ONE or TWO TIMES **
forvalues loop = `floop'/2 { 
    if `loop' == 2 {
        ** PREVENT EXCESSIVE # of ITERATIONS in BOOTSTRAP
        local ic2 = max(3*`ic',25)
if "itetrunc" == "" {
    local itetrunc "iterate('ic2')"
} else {
    local striter "itetrunc"
    local striter = regexr("striter","iterate",""")
    local striter = `striter'
    if `striter' > `ic2' {
        local itetrunc "iterate('ic2')"
    }
}

** ACCOUNT FOR DIFFERENT NUMB. OF REPS. **
if `loop' == 1 {
    local repsloop = `bcreps'
    local loopmark " (bias correction)"
} else {
    local repsloop = `reps'
    if `algorithm' == 2 {
        local loopmark " (conf. intervals)"
    } else {
        local loopmark ""
    }
}

** DISPLAY ITERATION HEADER **
if "'dots'" == "dots" {
    noi: display _newline as text "Bootstrap`loopmark' replications (" as result "'repsloop'" as text ")"
    noi: display as text ":(hline 4){c +}{hline 3} 1 {hline 3}{c +}{hline 3} 2 {hline 3}{c +}{hline 3} 3 {hline 3}{c +}{hline 3} 4 {hline 3}{c +}{hline 3} 5"
}

** START BOOTSTRAP ITERATIONS **
local bb = 1
local cc = 0
    while `bb' <= `repsloop' {
        local cc = `cc'+1
        ** ABORT BOOTSTRAP if MANY FAILURES **
            if `cc'-`bb' > `repsloop' {
                noi display as text "'cc'"
                noi display as error "'(p 0 2 2 'ls')excessive # of failed bootstr. reps; bootstr. aborted(p_end)"
                local repsloop = 'bb'
                local nbstrf = `cc'-`bb'
                if `bb' <= 2 {
                    foreach mmat in `__BB' `__BM' `__MatStar' `__DEABC' `__DEABIAS' `__DEAB' {

```
cap mata: mata drop `mmat'
}

ereturn clear

exit 498
}
else {

continue, break
}
}
cap drop `_rnn'

** DRAW FROM TRUNCATED NORMAL DISTRIBUTION **

if "unit" == ""|

if ("twosided" == "notwosided" & `loop' == 2) |
("logscore" == "logscore") {
        gen double    `_rnn' =
invnormal(runiform()*normal(`__ntruncfit'/`sig'))*`sig'
    }
else {
        gen double    `_rnn' =
invnormal(normal(`__ntruncfit'-1)/`sig') + runiform()*(normal(`__ntruncfit'/`sig') - normal(`__ntruncfit'-1)/`sig'))*`sig'
    }
}
else {
        gen double    `_rnn' =
- invnormal((1 - runiform())*normal(-`__ntruncfit'/`sig'))*`sig'
    }

** CHECK FOR FAILURE IN GENERATING PSEUDO ERRORS **

count if `_rnn' >=. & `__ntruncfit' <.
local simfail = r(N)

** SWITCH TAIL if FAILURE IN GENERATING PSEUDO ERROR **

if `simfail' > 0 {
        if "unit" == ""|

if ("twosided" == "notwosided" & `loop' == 2) |
("logscore" == "logscore") {
            replace    `_rnn' =
- invnormal(1 - runiform()*normal(`__ntruncfit'/`sig'))*`sig' if (`__rnn' >=. & `__ntruncfit' <.)
        } else {
            replace  `_rnn' =
- invnormal(1 - (normal(`__ntruncfit'-1)/`sig') + runiform()*(normal(`__ntruncfit'/`sig') - normal(`__ntruncfit'-1)/`sig'))) *`sig' if (`__rnn' >=. & `__ntruncfit' <.)
            }
        }
else {
            replace `_rnn' = invnormal(1 - ((1 - runiform())*normal(- `__ntruncfit'/`sig'))) *`sig' if (`__rnn' >=. & `__ntruncfit' <.)
        }
** CHECK AGAIN FOR FAILURES IN GENERATING PSEUDO ERRORS **
count if `__rnn' >=. & `__ntruncfit' <.
local simfail = r(N)
}
** CONTINUE IF FAILURE IN GENERATING PSEUDO ERRORS (Loop 2) **
if `simfail' > 0 & `loop' != 1 {
** DISPLAY ITERATION DOTS **
   if "dots" == "dots" {
      if `cc'/50 == round(`cc'/50) {
         noisily: display as error "x" as text " `cc"
      } else {
         noisily: display as error "x" _continue
      }
   continue
   }
   cap drop `__yboot'
** GENERATE BOOTSTRAP EFFICIENCY SCORES **
gen double `__yboot' = `__truncfit'+ `__rnn'
** LOOP 1: ESTIMATE BIAS-CORRECTED DEA-SCORES **
if `loop' == 1 {
** HANDLE PLUGIN te_radial **
if `cc' == 1 {
   handleplugin
   ** CREATE MATRIZES FOR PLUGIN **
mkmat `outps', matrix(`__yobs') nomissing
mkmat `inps', matrix(`__xobs') nomissing
mkmat `outps' if `__reference' == 1, matrix(`__yref') nomissing
mkmat `inps' if `__reference' == 1, matrix(`__xref') nomissing
scalar `__nO' = colsof(`__yobs')
scalar `__nI' = colsof(`__xobs')
scalar `__nobs' = rowsof(`__yobs')
scalar `__nref' = rowsof(`__yref')
scalar `__ifqh' = 1
scalar `__intovar' = 0
matrix `__teB'= J(`__nobs', 1, .)
matrix `__ystar' = `__yref'
matrix `__xstar' = `__xref'
** HANDLE RTS within PLUGIN **
if "rts" == "CRS" {
   scalar `__rt' = 3
}
else if "rts" == "NIRS" {
   scalar `__rt' = 2
}
else if "rts" == "VRS" {
   scalar `__rt' = 3
}
}
scalar `__rt' = 1
}
else {
   display as error "{p 0 2 2 `ls'}invalid returns to scale{p_end}"
   exit 198
}

** HANDLE BASE within PLUGIN **
if `"base'' == "output" {
    scalar `__ba' = 2
}
else if `"base'' == "input" {
    scalar `__ba' = 1
}
else {
    display as error "{p 0 2 2 `ls'}invalid base{p_end}"
    exit 198
}

** CONTINUE IF FAILURE IN GENERATING PSEUDO ERRORS (LOOP 1) **
if `simfail' > 0 {

** DISPLAY ITERATION DOTS **
if `"dots'' == "dots" {
   if `cc'/50 == round(`cc'/50) {
      noisily: display as error "x" as text " `cc''
   }
   else {
      noisily: display as error "x" _continue
   }
}
continue
}

** DETERMINE OBSERVATION-RANGE for REFERENCE **
local fref = `__nobs' - `__nref'+1
local lref = `__nobs'

** RESCALE VARS IN REFERENCE SET **
if `__ba' == 1 {
   ** CONSIDER LOGS IF OPTION LOGSCORE **
   if `"logscore'' != "logscore" {
      mata : `__MatStar' = st_matrix(`__xref') :* (st_data((`fref',`lref'), "yy'') / st_data((`fref',`lref'),"__yboot'')) :^(`expinvert')
   }
   else {
      mata : `__MatStar' = st_matrix(`__xref') :* exp((st_data((`fref',`lref'),"yy'') - st_data((`fref',`lref'),"__yboot''))) :^(`expinvert')
   }
   mata : st_matrix("__xstar''`, `__MatStar')
}
if `__ba' == 2 {
** CONSIDER LOGS IF OPTION LOGSCORE
if "logscore" != "logscore" {
    mata : `__MatStar' = st_matrix("__yref") :* (st_data(('fref', 'lref'), "yy") :/
        st_data(('fref', 'lref'), "__yboot")) :^(`expinvert')
} else {
    mata : `__MatStar' = st_matrix("__yref") :* exp((st_data(('fref', 'lref'),
        "yy") - st_data(('fref', 'lref'), "__yboot")) :^(`expinvert'))
    mata : st_matrix("__ystar", `__MatStar')
}
** CALL PLUGIN TO PERFORM DEA **
plugin call te_radial, `__yobs' `__xobs' `__nO' `__nI' `__nobs' `__ystar' `__xstar' `__nref' `__rt' `__ba' `ifqh' `intovar' `__teB'
** CONTINUE IF FAILED **
    if matmissing(`__teB') == 1 | rowsof(`__teB') != `__nobs'
    ** DISPLAY ITERATION DOTS **
        if "dots" == "dots" {
            if `cc'/50 == round(`cc'/50) {
                noisily: display as error "x" as text " `cc"
            } else {
                noisily: display as error "x" _continue
            }
        }
    continue
}
** DISPLAY ITERATION DOTS **
if "" == "" {
    if `cc'/50 == round(`cc'/50) | `bb' == `repsloop' {
        noisily: display as text ". `cc"
    } else {
        noisily: display as text "." _continue
    }
}
** COLLECT BOOTSTRAP DEA-SCORES **
if "bcsaveall" == "" {
    if `bb' == 1 {
        mata : `__DEAB' = st_matrix("__teB") :^(`expinvert')
    } else {
        mata : `__DEAB' = `__DEAB' + st_matrix("__teB") :^(`expinvert')
    }
} else {
    if `bb' == 1 {
mata : `__DEAB' = st_matrix("`__teB''") :^(`expinvert')
    }
else {
    mata : `__DEAB' = (`__DEAB', st_matrix("`__teB''") :^(`expinvert'))
}
}

** LOOP 2: TRUNCATED REGRESSION **
if `loop' == 2 {
** RUN TRUNCREG for BOOTSTRAP SAMPLE **
if "`unit'' == ""{
    if ("`twosided'' == "notwosided") | ("'logscore'' == "logscore") {
        cap truncreg `__yboot' `xx2' ['weight2' = `exp2'] if `yy' < `trlim', ul(`trlim')
        `constant' offset(`offset') `opttrunc' `itetrunc'
    }
} else {
    cap truncreg `__yboot' `xx2' ['weight2' = `exp2'] if `yy' < 1 & `yy' > 0, ll(0)
    ul(1) `constant' offset(`offset') `opttrunc' `itetrunc'
} else {
    cap truncreg `__yboot' `xx2' ['weight2' = `exp2'] if `yy' > `trlim', ll(`trlim')
    `constant' offset(`offset') `opttrunc' `itetrunc'
}
}

** CONTINUE IF FAILED **
if _rc != 0 | e(converged) != 1 {
** DISPLAY ITERATION DOTS **
if "`dots'' == "dots" {
    if `cc'/50 == round(`cc'/50) {
        noisily: display as error "x" as text " `cc''
    }
} else {
    noisily: display as error "x" _continue
}
}_continue

** DISPLAY ITERATION DOTS **
if "`dots'' == "dots" {
    if `cc'/50 == round(`cc'/50) | `bb' == `repsloop' {
        noisily: display as text ". `cc''
    }
} else {
    noisily: display as text ". _continue
}

** COLLECT BOOTSTRAP COEFFICIENT ESTIMATES **
if `bb' == 1 {
    mata : `__BB' = st_matrix("e(b)")
} else {
    mata : `__BB' = (`__BB' \ st_matrix("e(b)"))
}

** STOP BOOTSTRAP IF NUMB. of REQUESTED REPLICATIONS is REALIZED **
local bb = `bb'+ 1
if `bb' == `repsloop'+1 {
    local nbstrf = `cc'-(`bb'-1)
    continue, break
}

if `loop' == 1 {
    if "" != ""
        ** CALCULATE BIAS in DEA SCORES **
        if "" != ""
            mata : `__DEABIAS' = `__DEAB'/(`bb'-1) - `trlefte'(st_data(., "yy"))
        else {
            mata : `__DEABIAS' = (mean(`__DEAB'))' - `trlefte'(st_data(., "yy"))
        }
        ** SAVE BIAS in DEA SCORE PERMANATELY **
        gen double 'biaste' = .
        mata : st_store(.,"biaste",`__DEABIAS')
        label variable 'biaste' "bootstrap bias estimate for `printinvert'base'-oriented efficiency score under `rts'"
    }
    ** CALCULATE BIAS CORRECTED DEA-SCORES **
    if "" != ""
        mata : `__DEABC' = `trlefte'(st_data(., "yy")) - (`__DEAB'/(`bb'-1) - `trlefte'(st_data(., "yy")))
    else {
        mata : `__DEABC' = `trlefte'(st_data(., "yy")) - ((mean(`__DEAB'))' - `trlefte'(st_data(., "yy")))
    }
    ** CHECK FOR NON-POSITIVE BC-SCORES AND ISSUE WARNING **
    mata : st_numscalar("__cnps", min(`__DEABC'))
    if `__cnps' < 0 & "" != "noprint" {
        if "" != "input" {
            display as error "{p 0 2 2 `ls'}warning: bias-correction yields at least one negative score; consider specifying opt. invert or switching to base(output){p_end}"
        } else {
            display as error "{p 0 2 2 `ls'}warning: bias-correction yields at least one negative score; consider dropping opt. invert or switching to base(input){p_end}"
    else {
        }
mata : st_store(.,"`yy'","DEABC")
if "tebc" != ""
    ** SAVE BIAS CORRECTED DEA SCORE PERMANATELY **
    gen double `tebc' = `yy'
    label variable `tebc' "bias-corrected `base'-oriented efficiency score under `rts''"
}
** COUNT NEGATIVE SCORES **
if `_cnps' < 0 {
    count if `yy' < 0
    local nnneg = r(N)
}
** RE-COUNT LIMIT-SCORES (Count will be zero unless some error occurs) **
sum `exp2' if `yy' == 1
local wslim = r(sum)
local nnlim = r(N)
** RE-COUNT IRREGULAR SCORES **
if "unit" == "nounit" {
    sum `exp2' if `yy' < 1
    local wsirreg = r(sum)
    local nnirreg = r(N)
} else {
    sum `exp2' if `yy' > 1 & `yy' <.
    local wsirreg = r(sum)
    local nnirreg = r(N)
}
** TAKE LOGS IF OPTION LOGSCORE **
if "logscore" == "logscore" {
    replace `yy' = log(`yy')
}
** RE-RUN INITIAL TRUNCATED REGRESSION **
if "" == ""
if ("twosided" == "notwosided") | ("logscore" == "logscore") {
    cap `trn' truncreg `yy' `xx' [weight2 = `exp2'], ul(`trlim') `constant'
offset(`offset') `opttrunc' `itetrunc'
} else {
    cap `trn' truncreg `yy' `xx' [weight2 = `exp2'], ll(0) ul(1) `constant'
offset(`offset') `opttrunc' `itetrunc'
} else {
}
cap `trn' truncreg `yy' `xx' ['weight2' = `exp2'], ll(`trlim') `constant' offset('offset') 'opttrunc' `itetrunc'
    if _rc != 0 | e(converged) != 1 {
        display as error "(p 0 2 2 'ls')convergence not achieved in truncated regression(p_end)"
    }
    else {
        display as error "(p 0 2 2 'ls')truncated regression failed(p_end)"
    }
    ereturn clear
    mata : mata drop `__DEAB' `__DEABC' `__MatStar'
    if `biaste' != ""
        mata : mata drop `__DEABIAS'
    }
    restore
    if _rc != 0 {
        exit _rc
    }
    else {
        exit 430
    }
}
    local sig = e(sigma)
    cap drop `__truncfit' `__ntruncfit'
    predict double `__truncfit', xb
    gen double `__ntruncfit' = `trlim'-`__truncfit'
    matrix `__borg' = e(b)
** RE-CALCULATE SAMPLESIZE **
    sum `exp2' if e(sample)
    local wgtsum = r(sum)
    local tsamps = r(N)
** CHECK FOR EXTREMELY LARGE VALUES OF PREDICTED EFFICIENCY VALUES **
    if "unit" != "nounit" & "twosided" != "notwosided" & "logscore" != "logscore"
        count if max(abs(`__ntruncfit'),abs(`__ntruncfit'-1)) >= `extolerance'*`sig' &
        `__ntruncfit' <.
    }
    else {
        count if abs(`__ntruncfit') >= `extolerance'*`sig' &
        `__ntruncfit' <.
    }
    if r(N) > 0 {
        display as error "(p 0 2 2 'ls')extreme values for fitted efficiency encountered: 'dextval' > 'extolerance' for at least one DMU; bootstrap likely to fail; consider changing specification and check for possible outlier(s)(p_end)"
    }
    ereturn clear
    mata : mata drop `__DEAB' `__DEABC' `__MatStar'
if ""biaste"" != "" {  
    mata : mata drop `__DEABIAS'  
}  
restore  
extit 430  
}  
** TRANSFER RESULTS **  
local ic = e(ic)  
local k_eq = e(k_eq)  
local converged = e(converged)  
local rc = e(rc)  
    local ll = e(ll)  
local df_m = e(df_m)  
local k_aux = e(k_aux)  
** CHECK for CONSTRAINTS **  
if ""e(Cns)"" != "" {  
    matrix `__Cns' = e(Cns)  
    local iconstr "iconstr"  
}  
cap drop `__esamp'  
gen `__esamp' = 1 if e(sample)  
}  
if 'loop' == 2 {  
** CALCULATE BOOTSTRAP MEAN & BIAS **  
mata : `__BM' = mean(`__BB')  
mata : st_matrix("`__bbm',`__BM')  
local colsob = colsof(`__borg')  
local colsbb = colsof(`__bbm')  
if `colsob' != `colsbb' {  
    foreach mmat in `__BB' `__BM' `__MatStar' `__DEABC' `__DEABIAS' `__DEAB' {  
cap mata : mata drop `mmat'  
}  
ereturn clear  
restore  
di as error "p 0 2 2 'ls'conformability error; bias correction failedp_end"  
extit 503  
}  
else {  
mat `__bbias' = `__bbm' - `__borg'  
** CALCULATE COVARIANCE-MATRIX **  
mata : `__VB' = quadvariance(`__BB')  
mata : st_matrix("`__cov',`__VB')  
** CALCULATE PERCENTILE CONFIDENCE INTERVALS **  
cipsimarwilson 'level' `__BB' `__cip'  
}  
}  
** CLEAR MATA **  

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if "algorithm" == "2" {
    mata : mata drop `__MatStar' `__DEABC'
    if "biaste" != "" {
        mata : mata drop `__DEABIAS'
    }
    if "bcsaveall" != "" {
        mata : `__DEAB' = `__DEAB''
        capture mata : mata drop `bcsaveall'
        mata : mata rename `__DEAB' "bcsaveall''
    } else {
        mata : mata drop `__DEAB''
    }
}
if "saveall" == "" {
    mata : mata drop `__BB' `__VB' `__BM'
} else {
    mata : mata drop `__VB' `__BM'
    capture mata : mata drop `saveall'
    mata : mata rename `__BB' "saveall''
}

** RENAME RESULTS **
if "algorithm" == "1" {
    local scoretype "score"
} else {
    local scoretype "bcscore"
}

local nc = colsof(`__borg') - 1
local psig = 1 + nc'
mat `__coef' = `__borg'[1...,1..nc']
mat `__sig' = `__borg'[1...,psig..psig']

** RENAME COLUMNS FOR e(b) AND e(V) **
if `c(stata_version)' < 15 {
    mat coleq `__sig' = sigma
    mat colname `__sig' = _cons
} else if `c(userversion)' < 15 {
    mat coleq `__sig' = sigma
    mat colname `__sig' = _cons
} else {
    mat coleq `__sig' = /
    mat colname `__sig' = sigma
}
if "deasyntax" != "" & "algorithm" == "1" {
    if "tename" == "" {

mat coleq `__coef' = `scoretype'
local yynew "`scoretype''
}
else {
    mat coleq `__coef' = `tename'
    local yynew "`tename''
}
}
else if ""`deasyntax''" != "" & ""`algorithm''" == "2" {
    if ""`tebc''" == "" {
        mat coleq `__coef' = `scoretype'
        local yynew "`scoretype''
    }
    else {
        mat coleq `__coef' = `tebc'
        local yynew "`tebc''
    }
}
else {
    mat coleq `__coef' = `yy'
    local yynew "`yy''
}

    mat `__borg' = ('`__coef','__sig')
    local cn : colfullnames `__borg'
    matrix colnames `__cov' = `cn'
    matrix rownames `__cov' = `cn'
    matrix rownames `__cip' = `cn'
    matrix colnames `__cip' = cip'level':ll cip'level':ul
    matrix `__cip' = `__cip''
    matrix colnames `__bbias' = `cn'
    matrix colnames `__bbm' = `cn'

** RESTORE ORIGNIAL SAMPLE **
if ""`deasyntax''" == "" | (""`algorithm''" == "1" & "`tename''" == "") {
    keep `__tempid' `__esamp'
}
if ""`deasyntax''" != "" & "`algorithm''" == "1" & "`tename''" != "" {
    keep `__tempid' `__esamp' `savete'
}
if "`algorithm''" == "2" {
    local keepvar `__tempid' `__esamp''
    if "`savete''" == "" {
        local keepvar `keepvar' `savete''
    }
    if "`tebc''" == "" {
        local keepvar `keepvar' `tebc''
    }
    if "`biaste''" == "" {
        local keepvar `keepvar' `biaste''
    }
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keep `keepvar'

sort `__tempid'
    save `__resufile'
restore
merge 1:1 `__tempid' using `__resufile', nogenerate update replace force
replace `__esamp' = 0 if `__esamp' != 1

** CALCULATE NUMBERS OF OBSERVATIONS **
if "'weight2'" == "'iw'" {
    local samps = round(`wgtsum')
    local N_lim = round(`wslim')
    local N_all = round(`wsall')
    local N_irreg = round(`wsirreg')
} else {
    local samps = `tsamps'
    local N_lim = `nnlim'
    local N_all = `nnall'
    local N_irreg = `nnirreg'
}

** POST RESULTS TO e() **
ereturn clear
if "'iconstr'" == "'iconstr'" {
    ereturn post `__borg' `__cov' `__Cns', properties(b V) obs(`samps')
esample(`__esamp') findomitted
} else {
    ereturn post `__borg' `__cov', properties(b V) obs(`samps')
esample(`__esamp') findomitted
}

** WALD TEST of NULL-MODEL **
if `df_m' > 0 {
    test [`yynew']
    local wchi2 = `r(chi2)'
    local wp = `r(p)'
} else {
    local wchi2 = .
    local wp = .
}

** RANK OF e(V) **
mata : st_matrix("'rank'",rank(st_matrix("e(V)")))

** SCALARS **
ereturn scalar N = `samps'
ereturn scalar N_lim = `N_lim'
ereturn scalar N_all = `N_all'
ereturn scalar N_irreg = `N_irreg'

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if ""weight"" != "" { 
    *return scalar wgtsum = 'wgtsum'
}
*return scalar sigma = 'sig'
*return scalar ll = 'll'
*return scalar ic = 'ic'
*return scalar converged = 'converged'
*return scalar rc = 'rc'
*return scalar rank = 'rank'[1,1]
*return scalar k_eq = 'k_eq'
*return scalar df_m = 'df_m'
*return scalar k_aux = 'k_aux'
*return scalar chi2 = 'wchi2'
*return scalar p = 'wp'
    *return scalar N_reps = 'reps'
*return scalar N_misreps = 'nbstrf'
*return scalar level = 'level'
*return scalar algorithm = 'algorithm'
** SCALARS (DEA)**
if ""deasyntax"" != "" { 
    if ""algorithm"" == "2" { 
        *return scalar N_dea = 'nobs'
        if ""nnneg"" != "" { 
            *return scalar N_deaneg = 'nnneg'
        }
    }
    else { 
        *return scalar N_deaneg = 0
    }
    *return scalar N_dearef = 'nref'
    *return scalar N_bc = 'bcreps'
}
else { 
    *return scalar N_dea = 'ndeao'
    *return scalar N_dearef = 'ndearefo'
}
*return scalar ninps = 'nI'
*return scalar noutps = 'nO'
*
** MATRICES **
     *return matrix ci_percentile = 'cip'
     *return matrix bias_bstr = 'bbias'
*return matrix b_bstr = 'bmm'
** MACROS (DEA)**
if ""deasyntax"" != "" { 
    *return local outputs "\outps"
    *return local inputs "\inps"
    *return local base "\base"
    *return local rts "\rts"
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if "tename" != "" {
    ereturn local tename "tename"
}
if "tebc" != "" {
    ereturn local tebc "tebc"
}
if "biaste" != "" {
    ereturn local biaste "biaste"
}
ereturn local bcsaveall `bcsaveall'
ereturn local saveall `saveall'
ereturn local offset `offset'
ereturn local cinormal `cinormal'
ereturn local bbootstrap `bbootstrap'
if "deasyntax" == "" {
    ereturn local depvarname "yy"
}
if "deasyntax" != "" & "tename" != "" & "algorithm" == "1" {
    ereturn local depvarname "tename"
}
if "deasyntax" != "" & "tebc" != "" & "algorithm" == "2" {
    ereturn local depvarname "tebc"
}
if "deasyntax" != "" {
    ereturn local deatype "internal"
} else {
    ereturn local deatype "external"
}
ereturn local scoretype "scoretype"
** MACROS (else) **
ereturn local predict "truncr_p"
ereturn local marginsok "default XB E(passthru)"
if "unit" == "nounit" {
    ereturn local marginsdefault "predict(e(\`trlim\',.))"
} else if ("twosided" == "notwosided") | "logscore" == "logscore" {
    ereturn local marginsdefault "predict(e(.,\`trlim\'))"
} else {
    ereturn local marginsdefault "predict(e(0,1))"
}
    if "weight" != "" {
        ereturn local wexp "exp"
ereturn local wtype "weight"
    }
    if "unit" == "" {
        ereturn local wtype "weight"
    }
}
return local unit "unit"
else {
    return local unit `unit'
}
if "`e(unit)" == "unit" {
    return local depvar "efficiency"
} else {
    return local depvar "inefficiency"
}
if "invert" == "invert" {
    return local invert "Shephard"
} else {
    return local invert "Farrell"
}
if ("twosided" == "notwosided") | ("unit" == "nounit") | ("logscore" == "logscore") {
    return local truncation "onesided"
} else {
    return local truncation "twosided"
}
if "logscore" == "logscore" {
    return local logscore `logscore'
}
return local cmd `cmd'
return local cmdline `cmdline'
return local shorttitl e "Simar & Wilson (2007) eff. analysis"
return local title "Simar & Wilson (2007) two-stage efficiency analysis"
} set more `moreold'
else {
** HANDLE RE-DISPLAY OF RESULTS **
if "e(cmd)" != "simarwilson" {
    error 301
} else {
    syntax, [LEVEL(real `e(level)')] [CINormal] [BBOOTstrap]
    [CFORMAT(string asis)] [PFORMAT(string asis)] [SFORMAT(string asis)] [VSQUISH] [noPRINT]
    [noDEAPrint] [noOMITted] [BASELevels]
** GENERATE TEMPORARY MATRIX FOR PERCENTILE CIs **
tempname __cip
** HANDLE LEVEL **
    if `level' >= 10 & `level' <= 99.99 {
        local level = round(`level',0.01)
local level = substr("level",1,5)
}
else {
  if "print" != "noprint" {
    noisily display as error "(p 0 2 2 'ls')warning: level() outside [10,99.99] interval not allowed(p_end)"
    local level = `e(level)`
  }
/*
if "e(cinormal)" == "cinormal" {
  local cinormal "cinormal"
}
*/
}

** DISPLAY RESULTS **
** SET DISPLAY-OPTIONS (Deactivated!) **
if "cformat" == "" | "cformat" != "" {
  if "cformat" != "" & "cformat" != "%9.0g" & "print" != "noprint" {
    di as text "(p 0 2 2 'ls')sorry, spec. cformat('cformat') ignored(p_end)"
    local cformat "%9.0g"
  }
  if "pformat" == "" | "pformat" != "" {
    if "pformat" != "" & "pformat" != "%5.3f" & "print" != "noprint" {
      di as text "(p 0 2 2 'ls')sorry, spec. pformat('pformat') ignored(p_end)"
      local pformat "%5.3f"
    }
    if "sformat" == "" | "sformat" != "" {
      if "sformat" != "" & "sformat" != "%8.2f" & "print" != "noprint" {
        di as text "(p 0 2 2 'ls')sorry, spec. sformat('sformat') ignored(p_end)"
        local sformat "%8.2f"
      }
    }
  }
}

** SET DEFAULT DEPVARNAME (IF NOT SAVED TO e()) **
if "e(depvarname)" != "" {
  if "e(logscore)" != "logscore" {
    local edepvarname "e(depvarname)"
  }
  else {
    local edepvarname "ln(`e(depvarname)')"
  }
}
else {
  if "e(logscore)" != "logscore" {
    local edepvarname "e(scoretype)"
  }
}

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else {
    local edepvarname "ln(`e(scoretype)')"
}

** SET PARAMETERS FOR SKIPPING (determine values for _skip()) **
if "`e(unit)" == "unit" {
    local inq "<"
} else {
    local inq ">"
}
if "`e(logscore)" != "logscore" {
    local trlim = 1
} else {
    local trlim = 0
}

** ABBREVIATE TOO-LONG DEPENDENT **
local shortdvn = abbrev("edepvarname",20)
local inei "inefficient if `shortdvn"
if "`e(df_m)" != "" {
    if `e(df_m)' > 0 {
        local fskip = 1+floor(log10(`e(df_m)'))
    } else {
        local fskip = 1
    }
} else {
    local fskip = 1
}

** LOOP OVER STATISTICS TO BE DISPLAYED **
foreach disp in "Number of obs" "Number of efficient DMUs" "Number of bootstrap reps" "Wald chi2" "Prob > chi2" "Number of super-eff. DMUs" {
    local rr = `rr'+1
    if `rr' == 1 {
        local statskip `rr' = `statskip' - `strlen("e(shorttitle)"")
    }
}
local disp`rr' ""disp""
local ldisp`rr'= strlen(""disp"")
local skip`rr' = `statwidth' - `statwidth2' - `ldisp`rr''
if `rr' == 2 {
    local statskip`rr' = `statskip' - `strlen("algorithm #`e(algorithm)""))
}
if `rr' == 4 | `rr' == 5 {
    local skip`rr' = `statwidth' - `ldisp`rr'' - `fskip' - 1 - `statwidth2'
}
if `rr' == 4 {
    local statskip`rr' = `statskip' - `strlen("inei")")" - 4
}
if `rr' == 5 {
    local statskip`rr' = `statskip' - strlen("e(truncation)")" - 11
}

** DISPLAY RESULTS on SCREEN **
if ""e(wtype)"" != "" {
    di as text "(sum of wgt is " as text %10.7e `e(wgtsum)' as text ")"
}
    display _newline as text ""e(shorttitle)"" _skip(`statskip') as text ""disp1"" _skip(`skip1') as text " =  " as result %8.0f `e(N)'
    display as text "(algorithm #" as result "e(algorithm)" as text ")" _skip(`statskip2') as text " =  " as result %8.0f `e(N_lim)'**display _skip(`statskip') as text ""disp2"" _skip(`skip2') as text " =  " as result %8.0f 
    else {
            display _skip(`statskip') as text ""disp6"" _skip(`skip6') as text " =  " as result %8.0f 
    }
}
if `e(N_irreg)' > 0 & `e(N_irreg)' <. { 
    display _skip(`statskip') as text ""disp4"" _skip(`skip4') as text " =  " as result %8.4f 
    else {
            display as text ""inei" as result " inq" as text "trlim" _skip(`statskip4') as text 
    }
}
** DISPLAY DEA RESULTS on SCREEN **
if ""deaprint"" == "" { 

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display as text "\{hline `tabwidth'}"
local deatitleprint "Data Envelopment Analysis:"
display as text "Data Envelopment Analysis:" _continue
if ""e(noutps)" == "" & ""e(ninps)" == "" {  
  local exdeaprint "externally estimated scores"
  local exdeaskip = `tabwidth' - `strlen("deatitleprint") - `strlen("exdeaprint")'
  display _skip('exdeaskip') as text "\-exdeaprint\" _newline
} else {

  ** DISPLAY ORIENTATION **
  local ortprint "e(base) oriented \('e(invert)')"
  local ortskip = `strlen("ortprint")'
  ** DISPLAY RETURNS TO SCALE **
  if ""e(rts)"" == "VRS" {  
    local rtsprint "variable returns to scale"
  }
  if ""e(rts)"" == "NIRS" {  
    local rtsprint "nonincreasing returns to scale"
  }
  if ""e(rts)"" == "CRS" {  
    local rtsprint "constant returns to scale"
  }
  local rtsskip = `strlen("rtsprint")'
  ** DISPLAY BIAS CORRECTION **
  if ""e(N_bc)"" != ""
  1 {  
    local ibcprint "bias corrected efficiency measure"
  }
  else {
    local ibcprint "no bias correction"
  }
  local ibcskip = `strlen("ibcprint")'
  ** DISPLAY NUMBER of DMUs **
  local dmuprint "Number of DMUs"
  local dmuprint1 = `tabwidth' - `strlen("deatitleprint") - `strlen("e(N_dea)")'
  local dmuprint2 = `strlen("dmuprint")' - 1
  local dmuprint3 = `strlen("e(N_dea)")'
  display _skip('dmuprint1') as text "\"_skip('dmuprint2') as text "\"_skip('dmuprint3') as result "e(N_dea)"

  ** DISPLAY NUMBER of REFERENCE DMUs **
  local refprint "Number of ref. DMUs"
  local refprint2 = `strlen("refprint")' - 1
  local refprint3 = `strlen("e(N_dearef)")'
  if ""e(N_bc)"" != ""
  1 {  
    local refskip1 = `tabwidth' - `strlen("refprint")'
    display _skip('refskip1') as text "\"_skip('refskip2') as text "\"_skip('refskip3') as result "e(N_dearef)"
  }

267
else {
    local refskip1 = `tabwidth' - `statwidth' - `ortskip'
    display as text "`ortprint'" _skip(`refskip1') as text "`refprint'" _skip(`refskip2') as text "=" _skip(`refskip3') as result "`e(N_dearef)'"
}
** DISPLAY NUMBER of OUTPUTs **
local outpsprint "Number of outputs"
local outpsskip2 = `statwidthtext' - `str'len("outpsprint")) - 1
local outpsskip3 = `statwidthval' - `str'len("e(noutps)")
if ""e(N_bc)" != ""{
    local outpsskip1 = `tabwidth' - `statwidth' - `ortskip'
    display as text "`ortprint'" _skip(`outpsskip1') as text "outpsprint" _skip(`outpsskip2') as text "=" _skip(`outpsskip3') as result "e(noutps)"
}
else {
    local outpsskip1 = `tabwidth' - `statwidth' - `ortskip'
    display as text "`ortprint'" _skip(`outpsskip1') as text "outpsprint" _skip(`outpsskip2') as text "=" _skip(`outpsskip3') as result "e(noutps)"
}
** DISPLAY NUMBER of INPUTs **
local inpsprint "Number of inputs"
local inpsskip2 = `statwidthtext' - `str'len("inpsprint") - 1
local inpsskip3 = `statwidthval' - `str'len("e(ninps)")
if ""e(N_bc)" != ""{
    local inpsskip1 = `tabwidth' - `statwidth' - `rtsskip'
    display as text ""rtsprint"" _skip(`inpsskip1') as text "inpsprint" _skip(`inpsskip2') as text "=" _skip(`inpsskip3') as result "e(ninps)"
}
else {
    local inpsskip1 = `tabwidth' - `statwidth' - `ibcskip'
    display as text "ibcprint" _skip(`inpsskip1') as text "inpsprint" _skip(`inpsskip2') as text "=" _skip(`inpsskip3') as result "e(ninps)" _newline
} if ""e(N_bc)" != ""{
** DISPLAY NUMBER of REPS (BIAS CORRECTION) **
local bcprint "Number of reps (bc)"
local bcskip1 = `tabwidth' - `statwidth' - `ibcskip'
local bcskip2 = `statwidthtext' - `str'len("bcprint") - 1
local bcskip3 = `statwidthval' - `str'len("e(N_bc)")
    display as text "ibcprint" _skip(`bcskip1') as text "bcprint" _skip(`bcskip2') as text "=" _skip(`bcskip3') as result "e(N_bc)" _newline
}
}
if "cinormal" == "cinormal" {
** DISPLAY REGRESSION TABLE WITH NORMAL-APPROX-CIs **
local ccn = abbrev("e(depvar)",12)
local colsk = 13 - `str'len("ccn")
268
if "bbootstrap" == "" { 
    display _column(13) as text " {c |} Observed" _skip(3) "Bootstrap" _skip(27) "Normal approx." 
} 
else { 
    display _column(13) as text " {c |} Bootstrap" _skip(3) "Bootstrap" _skip(27) "Normal approx." 
}
display _column(`colsk') as text "`ccn' {c |} Coef." _skip(3) "Std. Err." _skip(6) "z" _skip(4) "P>|z|" _skip(`ciskip') "[ as result 'level' as text "% Conf. Interval]"
display as text "{hline 13}{c +}{hline 64}" 
local ccn = `substr'(abbrev("edepvarname",12),1,12) 
local colsk = 13 - `str'len("ccn") 
display as result "`ccn" as text _skip(`colsk') "{c |}"
** GEN TEMPORARY MATRICES FOR DISPLAY 
tempname __dima __dima2 __dima3 __dima4 __bt 
if "bbootstrap" == "" { 
    matrix `__bt' = e(b)' 
} 
else { 
    matrix `__bt' = e(b_bstr)' 
}
mata : st_matrix("__dima2", diagonal(st_matrix("e(V)")):^0.5) 
mata : st_matrix("__dima3", st_matrix("__bt"):/st_matrix("__dima2")) 
mata : st_matrix("__dima4", 2*normal(-1*abs(st_matrix("__dima3")))) 
matrix `__dima' = (`__bt',`__dima2', `__dima3', `__dima4', `__bt'+ invnormal((1-0.01*`level')/2)*`__dima2',`__bt'- invnormal((1-0.01*`level')/2)*`__dima2') 
} 
else { 
    ** DISPLAY REGRESSION TABLE WITH PERCENTILE-CIs ** 
    ** RECALCULATE PERCENTILE CIs if REQUIRED ** 
    if "e(level)" != "" & "e(saveall)" != "" { 
        cipsimarwilson `level` e(saveall) `__cip' 
        local nlevel = "level"
        mat scip = `__cip'
    } 
    else { 
        mat `__cip' = e(ci_percentile)' 
        local nlevel = "e(level)"
    } 
local ccn = abbrev("e(depvar)",12) 
local colsk = 13 - `str'len("ccn") 
display as text "{hline 13}{c TT}{hline 64}" 
if "bbootstrap" == "" { 
    display _column(13) as text " {c |} Observed" _skip(3) "Bootstrap" _skip(27) "Percentile" 
} 
}
else {
    display _column(13) as text " {c |} Bootstrap" _skip(3) "Bootstrap" _skip(27)
"Percentile"
}

display _column(`colsk') as text " {c |}" _skip(6) "Coef." _skip(3) "Std. Err." _skip(6) "z" _skip(4) "P>|z|" _skip(`cskip') 
"[" as result 'nivel' as text "% Conf. Interval"]
    display as text "{hline 13}{c +}{hline 64}"
local cn = `substr'(abbrev("`edepvarname'"),12),1,12)
local colsk = 13 - `str'len("`ccn'")
display as result ":`cn'" as text _skip(`colsk') "[c |]"
tempname __dima __dima2 __dima3 __dima4 __bt
if "`bbootstrap'" == ""
    matrix `__bt' = e(b)'
} else {
    matrix `__bt' = e(b_bstr')
}
    mata : st_matrix(`__dima2' , diagonal(st_matrix("e(V)"):^0.5)
    mata : st_matrix(`__dima3' , st_matrix(`__bt'):/st_matrix("__dima2''))
    mata : st_matrix(`__dima4' , 2*normal(-1*abs(st_matrix("__dima3''))))
    matrix `__dima' = (`__bt',`__dima2',`__dima3',`__dima4',`__cip')
local cn = rowsof(`__dima')
local cns : rownames `__dima'
tokenize `cns'
forvalue s cc = 1(1)`cn' {
    if `cc' == `cn' {
        local ccn "/sigma"
    } else {
        local ccn = abbrev("`cc'"),12)
    }
    local colsk = 13 - `str'len("`ccn'")
    if ("`omitted'" != "") & ("`baselevels'" == "baselevels" || `str'pos("`ccn'","b.'") == 0) {
    display _column(`colsk') as text " {c |}" _skip(2) as result `cformat' `__dima'[`cc',1] _skip(2) as result `cformat' `__dima'[`cc',2] _skip(1) as result `sformat' `__dima'[`cc',3] _skip(3) as result `pformat' `__dima'[`cc',4] _skip(3) as result `cformat' `__dima'[`cc',5] _skip(3) as result `cformat' `__dima'[`cc',6]}
    if `cc' == `cn'-1 {
        if ":e(offset)" != "" {
            local ccn = abbrev("e(offset)"),12)
            local colsk = 13 - `str'len("`ccn'")

    }
```
**** DISPLAY WARNING if CHANGE in LEVEL for PERCENTILE CIs is REQUESTED WITHOUT SPECIFYING SAVEALL() **
if replay() & "e(level)" != "level" & "cinormal" != "cinormal" & "e(saveall)" == ""

noisily display as error "p 0 2 2 It's saveall() not previously specified; cannot change level for percentile CIs; use opt. cinormal{p_end}"
}
** SAVE SOME RESULTS IN r() **
putr `__dima' `level'
end

*******************************************
********************************
*********************************
** PERCENTILE CONFIDENCE INTERVALS
**************************************************************************
***************************************************************************
**
capture program drop cipsimarwilson
program cipsimarwilson, nclass
version 12
    args level BB cip
    ** TEMPORARY NAMES **
tempname __CIB __CIBI __cc __rr
    mata : st_numscalar("__cc",cols(`BB'))
    mata : st_numscalar("__rr",rows(`BB'))
    local nb = `__cc'
    local llo = 1+floor(`__rr'*((100-`level')/200))
    local ulo = ceil(`__rr'-`__rr'*((100-`level')/200))
    local cw = min(max(((1-`level'/100)*`__rr'-(`__rr'-`ulo')+(`llo'-1)),0),2)
    forvalues cc = 1(1)`nb' {
        mata : `BB' = sort(`BB',`cc')
    }
    if `llo' > 1 & `ulo' < `__rr' {
        mata : `__CIBI' = (0.5+0.25*`cw')*(`BB'[`llo',`cc']`, `BB'[`ulo'+1,`cc'])
    }
    else {
        mata : `__CIBI' = (`BB'[`llo',`cc'], `BB'[`ulo',`cc'])
    }
    if `cc' == 1 {
        mata : `__CIB' = `__CIBI'
```

else {
    mata : `__CIB' = (`__CIB' \ `__CIBI')
}
}
mata : st_matrix("cip", `__CIB')
mata : mata drop `__CIB' `__CIBI'
end

**
DE-FACTOR-VARBLERIZE   VARLIST
***************************************************************************
*  
**
capture program drop defvar
program defvar, rclass
    syntax varlist(fv)
    local fvl "varlist"
    local dfvl ""
    foreach fo in "##" "#" { 
        local fvl : subinstr local fvl ""fo"", all
    }
    while ""fvl" != "" { 
        gettoken fi fvl : fvl, parse(" ") bind
        gettoken li ri : fi, parse("") bind
        if `c(stata_version)' < 14.2 {
            local str "str"
        }
        else {
            local str "ustr"
        }
        if `str'len("rr") != 0 {
            local dfvl "dfvl 'rr''"
        }
        else {
            local dfvl "dfvl 'fi'"
        }
        local dfvl : subinstr local dfvl "", all
        local dfvl : subinstr local dfvl ")", all
        local dfvl : subinstr local dfvl ":", all
        local dfvl : list uniq dfvl
        return local dfvl "dfvl"
    }
end
***************************************************************************
** HANDLE PLUGIN te_radial

********************************************************************************
******
********************************************************************************

**********************************
capture program drop handleplugin
program handleplugin, nclass
local os "upper(substr("c(os)",1,3))"
local vers = c(stata_version)
if `vers' >= 12 {
    local bit = c(bit)
    *display `bit'
}
if `os' == "MAC" {
    cap findfile te_radial/plugin
}
else if `os' == "UNI" {
    local mach "upper(substr("c(machine_type)",1,3))"
    if `mach' == "MAC" {
        cap findfile te_radial.plugin
    }
    else {
        cap findfile te_radial_ubuntu.plugin
    }
}
else if `os' == "WIN" {
    if `vers' >= 12 {
        if `bit' == 64 {
            cap findfile te_radial_windows.plugin
        }
        else {
            cap findfile te_radial_windows32.plugin
        }
    }
    else {
        cap findfile te_radial_windows32.plugin
    }
}
else {
    display as error "{p 0 2 2 `ls'}plugin to solve linear programming problem is not
available for your system; contact developers{p_end}"
exit 199
}
if _rc == 0 {
    capture program te_radial, plugin using ("`r(fn)"")
}
else {

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display as error "{p 0 2 2 `ls'}plugin to solve linear programming problem not found; check if teradial and the associated plugins are installed on your machine\{p_end}"
exit 199
end
***************************************************************************
*******************
** RETURN RESULTS IN r()
***************************************************************************
capture program drop putr
program putr, rclass
    args tabout levelout
    mat `tabout' = `tabout''
    mat rownames `tabout' = be se t pvalue ll ul
    return clear
    return matrix table = `tabout'
    return scalar level = `levelout'
end
Appendix 4: STATA output for OLS, Tobit and Simar & Wilson Regressions

Definitions of variables can be found in section 3.8.

```
. regress EfficiencyScore ln_NWP ReinsuranceRatio DerivativeUse FreeAssetRatio LiquidityRatio CentralLondon

Source | SS | df | MS | Number of obs = 1,019
---------+----+----+----+----------------------------------
Model | 38.8124565 | 6 | 6.46874276 | F(6, 1012) = 527.17 Prob > F = 0.0000
Residual | 12.4179802 | 1,012 | .01227039 | R-squared = 0.7576
---------+----+----+----+----------------------------------
Total | 51.2304448 | 1,018 | .050324602 | Root MSE = 0.71077

EfficiencyScore | Coef. | Std. Err. | t | P>|t| | [95% Conf. Interval]
---------+---------+------------+----+---------+-----------------------------
     ln_NWP |  .00754 |  .0015694 |  4.80 | 0.000 | .004604 - 0.0106196
 ReinsuranceRatio | -.0754035 |  .0147247 | -5.12 | 0.000 | -.104298 - -.046509
 DerivativeUse | -.0307979 |  .0083941 | -3.67 | 0.000 | -.0472698 - -.014326
 FreeAssetRatio |  .0242668 |  .0161661 |  1.50 | 0.133 | -.0074361 - .0560097
 LiquidityRatio |  .0192655 |  .0159476 |  1.21 | 0.227 | -.0120286 - .0505595
 CentralLondon | -.4201485 |  .0078233 | -53.70 | 0.000 | -.4355003 - -.4047967
     _cons |  .6569404 |  .0311906 | 21.06 | 0.000 | .5957347 - .7181461
```

```
. vif

| Variable | VIF | 1/VIF |
|----------+-----+-------|
| ln_NWP   | 1.62 | 0.617945 |
| LiquidityRatio | 1.41 | 0.711635 |
| Derivative | 1.35 | 0.742505 |
| FreeAssetRatio | 1.12 | 0.891622 |
| CentralLondon | 1.09 | 0.914896 |
| Reinsurance | 1.05 | 0.956647 |

Mean VIF | 1.27

. estat hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of EfficiencyScore

chi2(6) = 0.00
Prob > chi2 = 0.9663
. simarwilson EfficiencyScore ln_NWP ReinsuranceRatio DerivativeUse FreeAssetRatio LiquidityRatio CentralLondon
> , reps (2000)

Simar & Wilson (2007) eff. analysis  Number of obs = 986
(algorithm #1)  Number of efficient DMUs = 32
Number of bootstrap reps = 2000
inefficient if EfficiencyScore < 1  Wald ch\(i^2\) (6) = 4346.07
two-sided truncation  Prob > ch\(i^2\) (6) = 0.0000

Data Envelopment Analysis:  externally estimated scores

<table>
<thead>
<tr>
<th>efficiency</th>
<th>Observed</th>
<th>Bootstrap</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>Std. Err.</td>
<td>z</td>
</tr>
<tr>
<td>Efficiency</td>
<td>-.003247</td>
<td>.0014213</td>
<td>-.23</td>
</tr>
<tr>
<td>ln_NWP</td>
<td>-.0586673</td>
<td>.0124332</td>
<td>-4.72</td>
</tr>
<tr>
<td>Reinsuranc</td>
<td>-.0149381</td>
<td>.0072644</td>
<td>-2.06</td>
</tr>
<tr>
<td>Derivative</td>
<td>.0049877</td>
<td>.0137338</td>
<td>0.36</td>
</tr>
<tr>
<td>FreeAssetR</td>
<td>.0064279</td>
<td>.013884</td>
<td>0.46</td>
</tr>
<tr>
<td>LiquidityR</td>
<td>-.4250727</td>
<td>.0067872</td>
<td>-62.63</td>
</tr>
<tr>
<td>CentralLon</td>
<td>.7995842</td>
<td>.0280908</td>
<td>28.46</td>
</tr>
<tr>
<td>_cons</td>
<td>.0929901</td>
<td>.0022463</td>
<td>41.40</td>
</tr>
</tbody>
</table>
. xtrreg EfficiencyScore ln_NWP ReinsuranceRatio DerivativeUse FreeAssetRatio LiquidityRatio CentralLondon, re

Random-effects GLS regression Number of obs = 1,019
Group variable: insCo Number of groups = 160

R-sq: Obs per group:
within = 0.2431 min = 1
between = 0.8208 avg = 6.4
overall = 0.7518 max = 9

Wald chi2(6) = 971.94
corr(u_i, X) = 0 (assumed) Prob > chi2 = 0.0000

| EfficiencyScore | Coef.  | Std. Err. | z     | P>|z|  | [95% Conf. Interval] |
|-----------------|--------|-----------|-------|------|-----------------------|
| ln_NWP          | .0031863 | .0019881 | 1.60  | 0.109 | -.0007102 to .0070828 |
| ReinsuranceRatio| -.0274777 | .0150482 | -1.83 | 0.068 | -.0569715 to .0020162 |
| DerivativeUse    | -.0113484 | .0082706 | -1.37 | 0.170 | -.0275585 to .0048617 |
| FreeAssetRatio   | .0108967  | .0147653 | 0.74  | 0.461 | -.0180427 to .0398361 |
| LiquidityRatio   | -.0051783 | .017448  | -0.30 | 0.767 | -.0393758 to .0290193 |
| CentralLondon    | -.4058865 | .0131852 | -30.78| 0.000 | -.4317289 to -.380044  |
| _cons           | .726364   | .0397924 | 18.25 | 0.000 | .6483724 to .8043557  |

| sigma_u         | .08892744 |
| sigma_e         | .0578821  |
| rho             | .7024151   | (fraction of variance due to u_i) |

. xtest0

Breusch and Pagan Lagrangian multiplier test for random effects

EfficiencyScore[insCo,t] = Xb + u[insCo] + e[insCo,t]

Estimated results:

<table>
<thead>
<tr>
<th>Var</th>
<th>sd = sqrt(Var)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>.0503246</td>
</tr>
<tr>
<td>e</td>
<td>.0033503</td>
</tr>
<tr>
<td>u</td>
<td>.0079081</td>
</tr>
</tbody>
</table>

Test: Var(u) = 0

chibar2(01) = 2001.11
Prob > chibar2 = 0.0000

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. hausman fixed

<table>
<thead>
<tr>
<th></th>
<th>(b)</th>
<th>(B)</th>
<th>(b-B)</th>
<th>sqrt(diag(V_b-V_B))</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln_NWP</td>
<td>.0041641</td>
<td>.0031863</td>
<td>.0009778</td>
<td>.0017733</td>
</tr>
<tr>
<td>Reinsurance-o</td>
<td>-.0119041</td>
<td>-.0274777</td>
<td>.0155736</td>
<td>.0090042</td>
</tr>
<tr>
<td>Derivative-e</td>
<td>-.0070256</td>
<td>-.0113484</td>
<td>.0043229</td>
<td>.004174</td>
</tr>
<tr>
<td>FreeAssetR-o</td>
<td>.0070487</td>
<td>.0108967</td>
<td>-.003848</td>
<td>.0064777</td>
</tr>
<tr>
<td>LiquidityR-o</td>
<td>-.0140604</td>
<td>-.0051783</td>
<td>-.0088821</td>
<td>.0106059</td>
</tr>
<tr>
<td>CentralLon-n</td>
<td>-.3630058</td>
<td>-.4058865</td>
<td>.0428806</td>
<td>.018356</td>
</tr>
</tbody>
</table>

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

\[ \text{chi}^2(6) = (b-B)' \cdot [V_{b-V_B}]^{-1} \cdot (b-B) \]
\[ = 9.10 \]
\[ \text{Prob}>\text{chi}^2 = 0.1682 \]
Fitting comparison model:

Fitting constant-only model:

Iteration 0:  log likelihood = 5.6090128
Iteration 1:  log likelihood = 6.4301698
Iteration 2:  log likelihood = 6.4303044
Iteration 3:  log likelihood = 6.4303044

Fitting full model:

Iteration 0:  log likelihood = 693.61084
Iteration 1:  log likelihood = 694.48501
Iteration 2:  log likelihood = 694.48512
Iteration 3:  log likelihood = 694.48512

Obtaining starting values for full model:

Iteration 0:  log likelihood = 1232.9701
Iteration 1:  log likelihood = 1245.2463
Iteration 2:  log likelihood = 1245.6769
Iteration 3:  log likelihood = 1245.6779

Fitting full model:

Iteration 0:  log likelihood = 1146.2787
Iteration 1:  log likelihood = 1147.0028
Iteration 2:  log likelihood = 1147.0047
Iteration 3:  log likelihood = 1147.0047

Random-effects tobit regression

Number of obs = 1,019
Uncensored = 986
Limits: lower = 0
upper = 1
Left-censored = 1
Right-censored = 32

Group variable: insCo
Number of groups = 160

Random effects u_i - Gaussian
Obs per group:
min = 1
avg = 6.4
max = 9

Integration method: mvaghermite
Integration pts. = 12

Log likelihood = 1147.0047
Wald chi2(6) = 890.97
Prob > chi2 = 0.0000

| EfficiencyScore | Coef. | Std. Err. | z     | P>|z| | [95% Conf. Interval] |
|-----------------|-------|-----------|-------|------|----------------------|
| ln_NWP          | 0.0036362 | 0.0020491 | 1.77 | 0.076 | -0.00038 | 0.0076524 |
| ReinsuranceRatio| -0.0297356 | 0.0155257 | -1.92 | 0.055 | -0.601654 | 0.0006943 |
| DerivativeUse    | -0.0115229 | 0.008473  | -1.36 | 0.174 | -0.2841085 | 0.0050838 |
| FreeAssetRatio   | 0.0116719 | 0.0151016 | 0.77 | 0.442 | -0.0179807 | 0.0041264 |
| LiquidityRatio   | -0.0040506 | 0.0178846 | -0.23 | 0.815 | -0.0411037 | 0.0290025 |
| CentralLondon    | -0.4063031 | 0.0173771 | -29.50 | 0.000 | -0.732938 | -0.0793124 |
| _cons            | 0.719495  | 0.0410153 | 17.55 | 0.000 | 0.639561 | 0.8003381 |

/ sigma_u = 0.0936761 | 0.0057108 | 16.40 | 0.000 | 0.0824831 | 0.1046691 |
/sigma_e = 0.0590479 | 0.0014498 | 40.73 | 0.000 | 0.0562063 | 0.0618895 |

rho = 0.7156506 | 0.0268667 | 660.8178 | 0.7658481 |

LR test of sigma_u=0: chibar2(01) = 905.04
Prob >= chibar2 = 0.000

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